

ST. MARYS RIVER
WATER QUALITY INVESTIGATIONS
1973-74

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PREFACE

The findings reported here are based on investigations conducted during 1973 and 1974 and reflect the water quality status of the river prior to the recent completion of several major abatement programs. The study therefore provides a basis for comparison with water quality conditions after the effects of these remedial measures have been fully realized.

Since the time of the study, major abatement progress has been made by the Algoma Steel Corp., Abitibi Paper Co. Ltd. and Domtar Chemical Ltd. located in Sault Ste. Marie, Ontario.

Algoma Steel has expanded coke oven operations and installed a new coke oven by-product plant. Although this was completed before the end of 1976, commissioning problems resulted in delays. These facilities reached full operational status at the end of 1977.

The primary treatment flotation system installed by Abitibi Paper Co. Ltd. became operational in July 1976; however, the system did not operate on a continuous basis. Heavy bark and sand particles fouled the system, requiring frequent shutdowns. This problem necessitated the installation of a pretreatment system in the woodroom. Occasional interruptions in treatment still occur but both systems have essentially operated on a continuous basis since June 1977.

At the time of this study, Domtar Chemical was discharging oil separator effluent at a rate of $13.6 \text{ m}^3/\text{d}$ with a phenol loading of 25 kg/d through the sanitary system to the municipal sewage treatment plant. Since January 1976, phenolic wastes have been incinerated pending the installation of a satisfactory treatment system.

Domtar discharges cooling water to Bennett Creek at a rate of $393 \text{ m}^3/\text{d}$. Prior to the installation of non-leaking cooling coils in late 1976, this effluent contained $60 \text{ } \mu\text{g/l}$ phenol. Since that time, the phenol concentration has been $7 \text{ } \mu\text{g/l}$.

The City of Sault Ste. Marie, in conjunction with this Ministry and a consulting firm, is presently assessing alternatives for upgrading the existing sewerage system and providing additional treatment capacity for future growth. It is anticipated that a second sewage treatment plant will be operational by the early 1980's.

Ministry studies of the St. Marys River conducted subsequent to data reported here have indicated that water quality conditions in 1975 were similar to those observed in 1974. In 1976, a prolonged excessive discharge of phenol from Algoma Steel resulted in abnormally high levels in the river and led the Ministry to prosecute the Company. With the exception of phenol levels, water quality remained unchanged from previous years.

Five monitoring surveys of the river were completed in 1977. These should reflect improvements in water quality as a result of abatement measures. In addition to monitoring surveys planned for 1978, the Field Bioassay Laboratory of the Ministry's Northeastern Region is initiating an intensive appraisal of effluents from Algoma Steel. An attempt will be made to identify the contribution of cyanides and phenols to effluent toxicity. The findings of these investigations will be the subject of a future report.



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SUMMARY OF FINDINGS

Water quality throughout most parts of the St. Marys River was found to be generally satisfactory and basically resembled that of Lake Superior. Biota, sediments and water quality along the U. S. shore of the river and in Lake Nicolet indicated that conditions were good and that this area could sustain a variety of water uses.

Water quality impairment was restricted to a narrow band along the Canadian shore. Natural and man-made constraints favour much lower river flows along the Canadian shore than on the opposite side which coupled with the lateral discharge from the Edison Sault Hydro-electric Power Canal tend to confine the contaminants to the Ontario shoreline.

The major industrial sources contributing to water quality impairment are Algoma Steel Corporation Ltd. and Abitibi Paper Company. While partial recovery from the effects of these industrial inputs takes place through the Lake George Channel, discharges from the Sault Ste. Marie sewage treatment plant (STP) delay the restoration of satisfactory water quality.

AESTHETIC IMPAIRMENT

In recent years, the occurrence of aesthetic problems has become less frequent than previously observed. Mats of oily fibrous material mixed with fine wood chips are noticed only occasionally on the Sault St. Marie waterfront extending as far as the Lake George Channel. These intermittent problems are in part due to the decomposition of fibres and fine wood particles found to be prevalent in the river sediments along the Canadian shore. The confinement of occasional oil slicks to the Algoma slip area suggests that oil booms are effective in containing the spills.

TOXIC SUBSTANCES

Phenols, cyanide, ammonia and heavy metals inputs from Algoma Steel are contaminants of concern because of their potential toxicity.

In general, the effect of these toxic substances did not extend beyond Lake George and Lake Nicolet. These lakes were characterized by low levels of contaminants in water and sediment, the presence of invertebrates sensitive to pollution and low levels of heavy metals and organics in fish.

Although phenol levels in 1974 decreased from those found in previous years, they continued to exceed the Great Lakes Water Quality Agreement objective for a distance of 11 km

downstream of Algoma or as far as Little Lake George in a band extending 100-130 m from the Canadian shore. Cyanide levels were in non-compliance with the Ministry criterion for public water supply up to a distance of 300 m downstream from the terminal basin outfall.

The occurrence of the highest concentrations of iron and zinc in water coincided with peaks in phenol, cyanide and ammonia. The simultaneous presence of these contaminants is of concern because of their possible synergistic action resulting in increased toxicity to aquatic biota. Static bioassays carried out by the Ministry revealed that the effluent of the main trunk sewer is toxic at 2% (by volume) after an exposure time of 96 hr. Estimates of toxicity of the receiving waters, based on the assumption of simple additive effects, indicated that waters as far as 3 km from the terminal basin discharge and extending 100m from the shore may be toxic to fish and aquatic biota. Benthic fauna evaluation also indicated that zones of toxicity characterized by disrupted invertebrate communities were present in the Algoma slip and in a zone downstream from the terminal basin. Sediments downstream from Algoma Steel discharges were found to be impaired and exceeded Ministry criteria used in evaluating dredging projects. They contained elevated levels of ether soluble compounds, iron, zinc and cyanide.

SETTLEABLE ORGANICS

Wood particles were noted in sediments along the Canadian shore of the river downstream from Abitibi Paper Co. and as far as Little Lake George. Wood fibres together with iron oxide particles contributed to the disruption of benthos.

The sediments downstream from the STP outfall were characterized by an abundance of decomposing organic matter for a distance of 2 km and were colonized by tubificid species characteristic of organic enrichment.

BACTERIAL CONTAMINATION

Bacterial counts in the river were in compliance with the Water Quality Agreement objectives and Ministry criteria for body contact recreation with the exception of localized areas along the City of Sault Ste. Marie, Ontario waterfront and downstream from the sewage treatment plant.

RECOMMENDATIONS

Based on findings of this study, the following recommendations were made in support of remedial programs already underway and to address additional issues identified through this study.

ALGOMA STEEL CORPORATION LTD.

In recognition of the detrimental effects of the Algoma Steel discharges on the St. Marys River, the Ministry issued an order to the company requiring it to reduce its waste loadings. As part of the Company's over-all expansion program, new treatment facilities in the coke oven plant and modification to the existing phenol recovery plant to improve its efficiency were to be completed by the end of 1976. It was anticipated that the contaminants levels would be reduced to: phenol 58 µg/l; ammonia 0.35 mg/l; cyanide 0.047 mg/l and hydrogen sulphide 0.075 mg/l.

While reduction of these contaminants will improve the effluent quality, inputs of iron and zinc will still contribute to the impairment of sediments and benthic fauna in the river. *It was therefore recommended that Algoma Steel take steps to reduce iron and zinc in plant effluents so that levels in the Algoma slip waters and at the periphery of the mixing zone downstream from the terminal basin do not exceed 300 µg/l and 30 µg/l for iron and zinc, respectively.*

..... Recommendation 1

Waste waters from Algoma operations are discharged through a number of sewers. Only the terminal basin outlet is equipped with a flow measuring device. To better determine the magnitude and variability of waste loadings, *it was recommended that flow measuring devices be installed at the outlets of the bar and strip basin, Dorr thickener and blast furnace (60" and 30") discharges since the total discharge from these sewers is estimated to represent about 40% of the total wastewaters from Algoma Steel.*

..... Recommendation 2.

ABITIBI PAPER COMPANY

In the past, the Company discharged large quantities of wood particles and fibres which accumulated in downstream reaches of the river. In an attempt to reduce its suspended solids loading, the company installed flotation units in July 1976.

These did not operate on a continuous basis. Heavy bark and sand particles clogged the system, requiring frequent shut-downs. Resolution of the problem required that Abitibi

instal a pretreatment system in the woodroom to remove the offending material. By June of 1977, both systems became operational.

It was recommended that the Ministry assess the effectiveness of the abatement measures by conducting follow-up studies in the area.

..... Recommendation 3

MUNICIPAL DISCHARGES

Discharges from the sewage treatment plant are made through two submerged outfalls to the Lake George Channel. As the water head above the outfall is about 1 m, the initial dilution is negligible and the main dispersion mechanism occurs through water movement. As a result, the accumulation of decomposing organic matter across the width of the Lake George Channel was evident. The presence of phenolic wastes in the effluent may cause taste and odour problems. Accordingly, it was recommended that the Ministry investigate, in co-operation with the city, a means of eliminating phenolic discharges from the plant and of minimizing the discharge and deposition of settleable organics.

..... Recommendation 4

The occurrence of pollution from urban drainage is documented in this report. Levels of bacteria exceeded Water Quality Agreement objectives and Ministry criteria for total body contact recreation. It was therefore recommended that the Ministry together with the municipality take steps to control the discharge of untreated sanitary wastes to the river.

..... Recommendation 5

INTRODUCTION

The maintenance of a high level of water quality in the St. Marys River is one of the major concerns in the Upper Lakes system. The river is a source of water supply for a sizable urban and industrial area, is a major tourist attraction and provides a vital habitat for many important fish species. Therefore, degradation of this quality can have serious implications to water use; a problem which concerns citizens of both Canada and the United States.

Degradation resulting from steel and paper mill discharges has been documented since the 1940's and has been manifested in impairment of water quality, sediments and the zoobenthos. Considerable progress has however, been made since 1970 by Algoma Steel Corporation Ltd. in reducing phenol discharges, by Abitibi Paper Company Ltd. in reducing suspended solids loading and by the municipality in improving the removal of settleable organic matter.

As part of Ontario's contribution to the three-year International Reference Study on the pollution problems of Lake Huron and Lake Superior, the Ministry intensified assessment activity in the river in 1973 and 1974 for the purposes of:

- Determining the current water quality status in light of improvements in waste treatment
- Predicting the ultimate effectiveness of ongoing remedial measures in restoring river water quality
- Investigating the need for further remedial actions

Information was also required to assess water quality in terms of Agreement objectives and to investigate the transboundary movement of pollutants.

This report discusses the quality of water, sediment and biota in the river and the potential toxicity of industrial discharges. An attempt was made to define allowable mixing zones for industrial and municipal discharges.

DESCRIPTION OF STUDY AREA

The St. Marys River is the connecting waterway between Lake Superior and Lake Huron. The upper portion of the river extends from Whitefish Bay to the St. Marys rapids. A series of works (locks, power diversion channels, regulating gates) have been constructed as aids to control the outflow of Lake Superior for navigation and for power development.

The lower river has an irregular shoreline and contains three large islands, Sugar and Neebish Islands on the U.S. side and St. Joseph Island on the Canadian side (Figure 1). Sugar Island diverts the river below the locks into two channels Lake Nicolet into the west and middle channels while St. Joseph Island subdivides the flow from Lake George into the middle and east channels.

GEOLOGY AND TOPOGRAPHY

The rock formations of the land bordering the St. Marys River consist of schists, granite and diabases of Precambrian age which are mantled and in places deeply buried beneath glacial drift.

The area on the Canadian side which borders the St. Marys River is a drift-covered strip from one to five miles in width. The land surface rises toward the north in a succession of terraces and reaches a maximum altitude of about 120 m above the mean water surface elevations of both Lake Superior and Lake Huron which are 180 m and 175 m above sea level, respectively. On the United States side, the topography is characterized by gradually rising terrain which develops into a flat area with an altitude of about 90 m above the bordering lakes (1).

WATER USES

Domestic Water Use - The Upper St. Marys River is the source of supply for the U. S. and Canadian cities of Sault Ste. Marie. The total average pumpage from the river is 0.4 m³/s. No public water supply is taken from the lower St. Marys River. A portion of the Canadian Sault is supplied by wells.

Industrial Water Use - Algoma Steel and the Abitibi Paper Company withdraw water from the river at a rate of 578,000 m³/d and 65,000 m³/d, respectively.

Power and Irrigation - The Great Lakes Power Corporation Plant located between the Canadian lock and the mainland uses approximately 500 m³/s while the United States Government's Hydro-electric plant located between the U. S. locks and the rapids requires about 350 m³/s. The Edison Sault hydro-

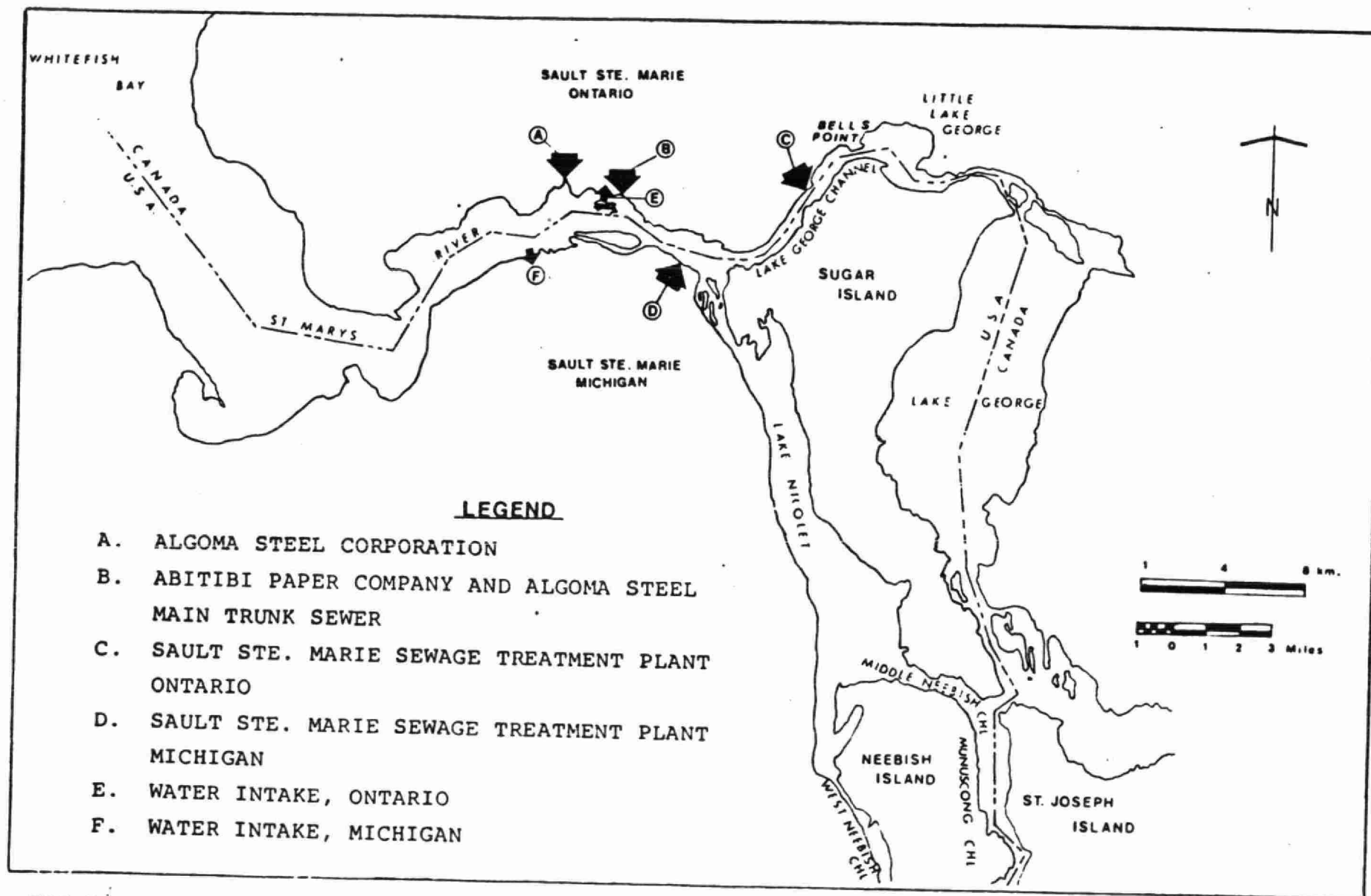


FIGURE 1: ST. MARYS RIVER - MUNICIPAL INTAKES, OUTFALLS AND INDUSTRIAL WASTE DISCHARGES

electric power plant is served by a 4 km long canal which diverts water from a point just above the U. S. locks and delivers it to the plant at a rate of 835 m³/s. The above uses do not add pollutants to the river, however, they alter the pattern of currents in the system.

Sault Ste. Marie, Ontario, Golf and Country Club pumps 0.01 m³/s during the summer for irrigation purposes.

Navigation - Vessel traffic through the locks is very heavy. The average number of vessels passing through the locks in the past 20 years decreased from 26,122 vessels in 1953 to 12,712 in 1970 (2). In recent years, shipping remained close to the 1970 level and carried 100 million tons of cargo per year. The vessels carry mainly crude oil, grain, steel, coal and petroleum products, taconite and iron ore between Lake Superior and the industrial centres on the lower lakes.

Recreation - The bays and lakes in the lower river provide areas with excellent recreational possibilities. Park use is intensive in the two parks nearest the cities of Sault Ste. Marie. There is private bathing along all parts of the river other than the immediate vicinity of the cities. The Algoma Health Unit restricts swimming in the river from the locks to Bells Point at Little Lake George. Boating and fishing are popular forms of recreation throughout the entire area.

WASTE DISPOSAL

Locations of municipal and industrial discharges from both the Canadian and U. S. shores into the river are shown in Figure 1. Municipal waste waters from both cities are treated in primary plants with chlorination facilities. The effluent from the Ontario plant (STP) is discharged to the Lake George Channel at a rate of 0.6 m³/s while that of the U. S. is discharged to the river at a rate of 0.17 m³/s.

Total loadings from the Ontario plant in 1974 were as follows:

Parameters	Loadings (kg/d)
BOD ₅	2150
Total Dissolved Solids	18227
Total Phosphorus	163
Total Kjeldahl Nitrogen	1000
Nitrate	10
Ammonia	700
Chloride	2570

Industrial waste discharges from Sault Ste. Marie, Ontario total $7.2 \text{ m}^3/\text{s}$ and are distributed as follows: Algoma Steel Corp. Limited and Algoma Steel Tube Division discharge $6.4 \text{ m}^3/\text{s}$; and Abitibi Paper Company discharges $0.8 \text{ m}^3/\text{s}$. There are no industrial discharges from Sault Ste. Marie, Michigan to the river.

As shown below, the Algoma main trunk sewer of the terminal basin discharges a significant portion of the total waste loadings from the steel mill. In 1974, these were:

Parameter	Total Loading (kg/d)	% Loading discharged from Main Trunk Sewer
Total Dissolved Solids	73,000	64
Phenol	200	98
Ammonia	11,000	99
Cyanide	2,280	95
Ether Soluble Substances	1,930	87
Iron	5,000	80

Trend analyses for the effluent quality of the terminal basin during 1972-74 (Fig.2) indicated that phenol and ammonia levels during 1974 were significantly lower than previously observed. Cyanide, however, did not reveal significant changes during the same period.

The other main industrial waste water discharge is from the Abitibi Paper Co. This discharge takes place through the main mill sewer and the sulphite sewer. The later, however, has been terminated. The total flow from the main mill sewer is $0.8 \text{ m}^3/\text{s}$. The loadings in 1974 were as follows:

Parameter	Loadings (kg/d)
Total Dissolved Solids	13,270
Total Suspended Solids	9,000
Phenol	7
BOD ₅	5,800

In 1974, Domtar Chemical discharged oil separator effluent at a rate of $13.6 \text{ m}^3/\text{d}$ with a phenol loading of 25 kg/d through the sanitary system to the sewage treatment plant. Cooling water was discharged to Bennett Creek at a rate of $393 \text{ m}^3/\text{d}$ with a phenol concentration of $60 \text{ } \mu\text{g/l}$.

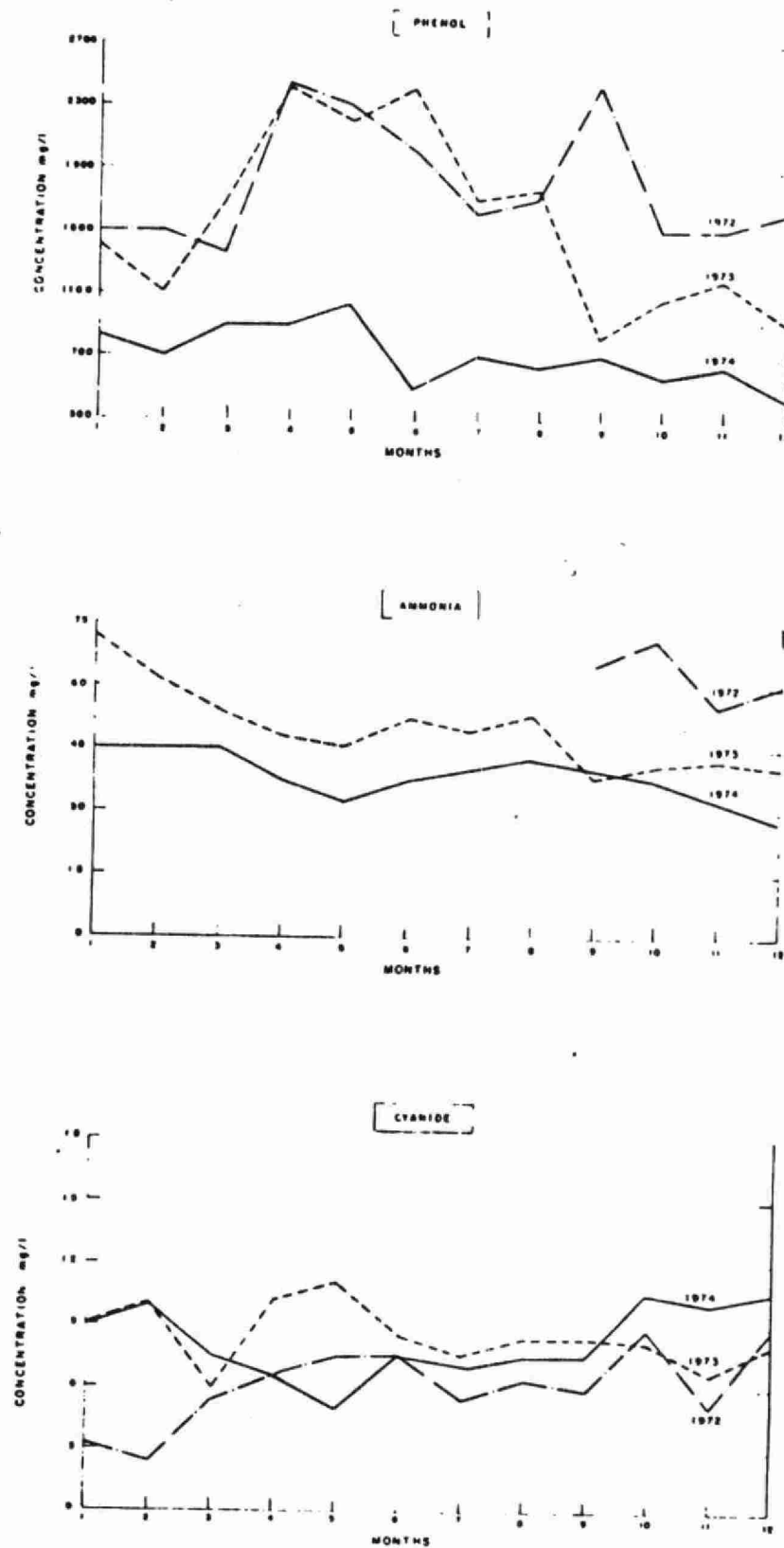


FIGURE 2: YEARLY TRENDS OF EFFLUENT QUALITY - ALGOMA STEEL MAIN TRUNK SEWER

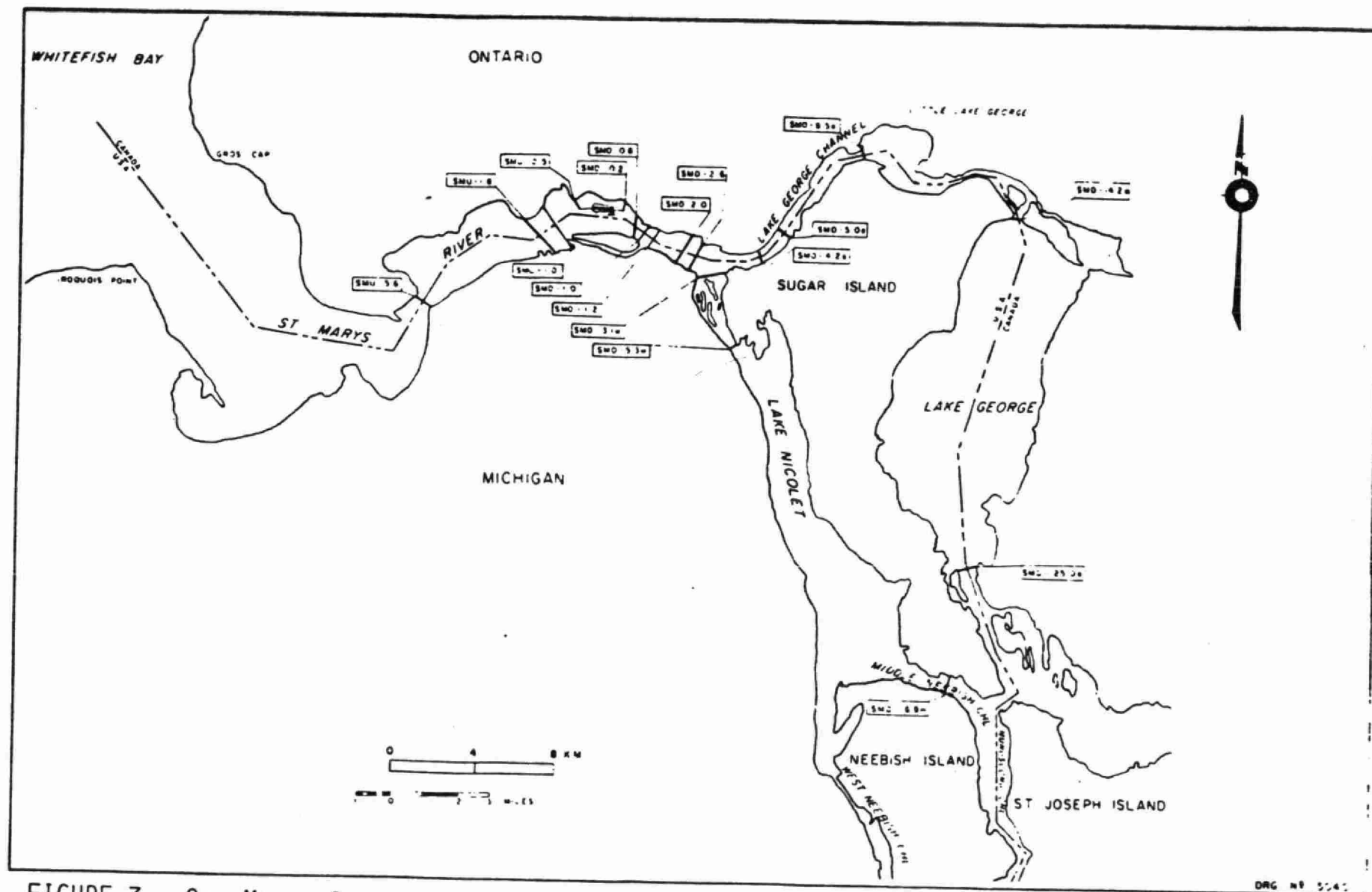
SURVEY METHODS

WATER QUALITY

A system of eleven sampling ranges across the river was used in monitoring water quality (Figure 3). The Ministry has used these sampling ranges for water quality investigations since 1967 with slight changes. Each range was sampled at several locations from the Canadian shore to the U. S. shore to detect transboundary pollution. The water quality parameters which were considered in this study are: phenol, cyanide, ammonia, total phosphorus, total iron, total and fecal coliform, fecal streptococci, heterotrophic bacteria and *Pseudomonas aeruginosa*.

SEDIMENT AND BOTTOM FAUNA

The survey of macroinvertebrate communities in St. Marys River was carried out during May-August 1973. The station locations (Figure 4) were based on a grid established during a previous survey conducted by the Ministry in 1968 (3). Some additional stations were established during the present survey in order to better assess conditions on the American side of the river. Two samples were taken at each of the 94 stations with a Ponar dredge. The physical characteristics of the sediments were noted in the field. Samples were screened through a 24 mesh screen (0.65 mm aperture) and the organisms were separated from the sediment and preserved in 95% ethanol for subsequent identification and enumeration. Selected stations were sampled again during July-October 1973 and the collected sediments analysed for total phosphorus, total nitrogen, organic carbon, cyanide, ether soluble compounds, phenolic compounds, iron, zinc and PCB content.



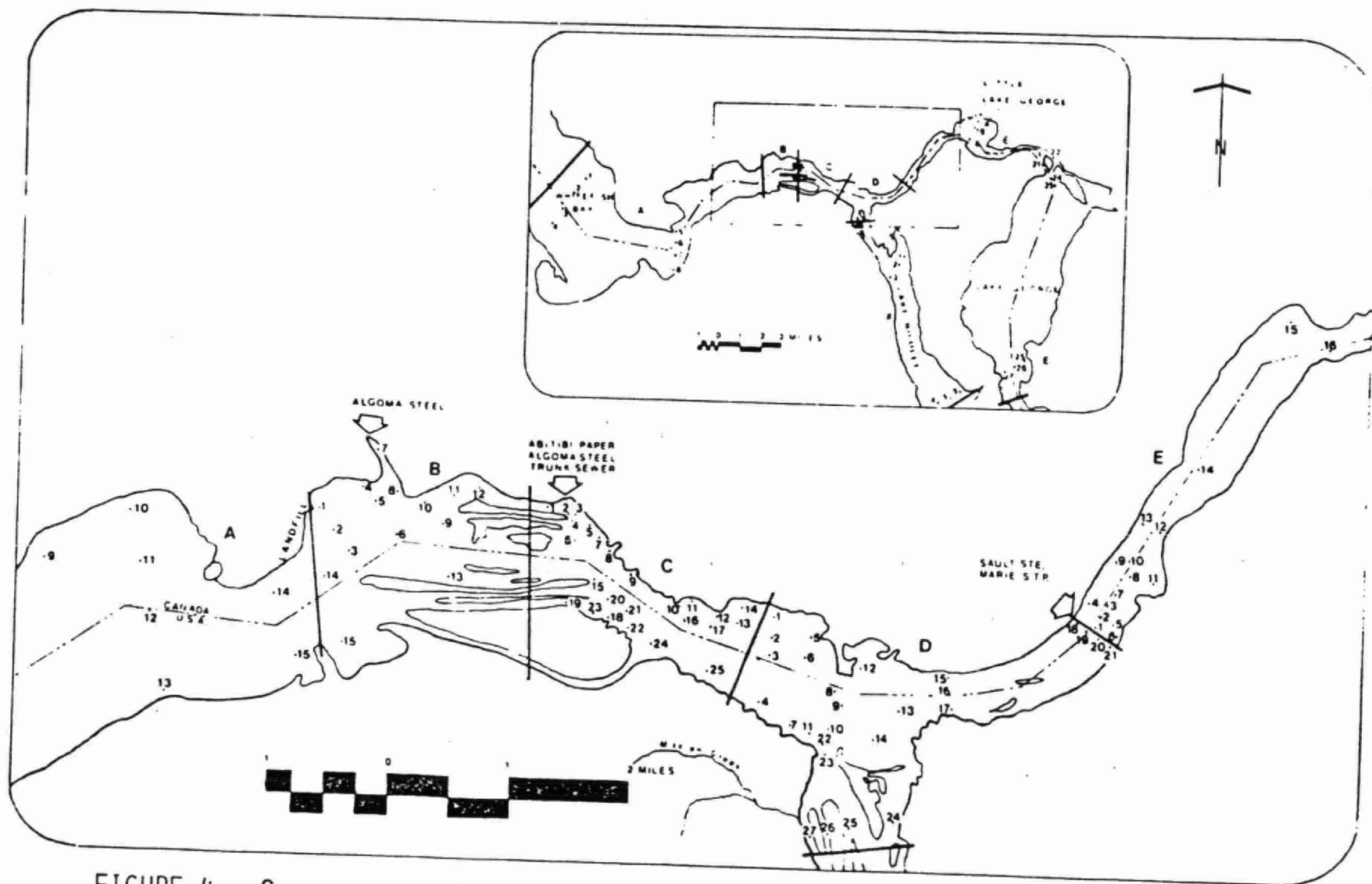


FIGURE 4: SEDIMENT AND BENTHIC FAUNA STATION LOCATIONS

DISCUSSION OF RESULTS

WATER QUALITY

The study findings are discussed under the headings Toxic Substances, Bacterial Contamination and Enrichment.

Toxic Substances

Phenol, ammonia, cyanide and heavy metals are the major toxic constituents in the steel mill effluent. Temporal trends for these components were examined during the period 1970-74 to assess the efficiency of treatment system modifications introduced by Algoma Steel in 1970. These included a phenol recovery plant and a diffuser outfall for the main trunk sewer of the terminal basin.

Phenols

Algoma Steel is a major source of phenol input to the river. The distribution of phenol levels along the Canadian and U.S. shores is illustrated in Figure 5. Phenols decreased from an average level of 24 $\mu\text{g/l}$ at 300 m downstream from the main trunk sewer to about 10 $\mu\text{g/l}$ at 3.2 km downstream from the outfall. The latter concentration persisted in the Lake George Channel and was augmented by the discharge of the STP which contained phenol from Domtar Chemical. During the study period, this industry discharged 25 kg/day of phenol to the sanitary system.

Conditions for the formation of chlorophenol compounds existed in the STP effluent. These substances can affect the palatability of fish and produce taste and odour in water supplies. However, no confirmed reports of tainting have been received.

Along the U.S. shore and at the outlet of Lake George, phenol levels of 2 $\mu\text{g/l}$ comparable to those at the headwaters of the river were observed. Discharges of phenol from the St. Marys River to the North Channel have no serious impact as evidenced by phenol levels of 1 $\mu\text{g/l}$ in the latter.

Year-to-year variations of phenol levels are shown in Figure 6. It is difficult to assess trends for the period prior to 1970 because of infrequent measurements along the Canadian shore during this period. Indications are, however, that a decrease has occurred between the period 1963-69 and 1970-74, likely due to the introduction of the phenol recovery plant and the diffuser outfall. A detailed multi-comparison test among the mean cruise levels for the latter period indicated that 1974 levels were significantly lower than

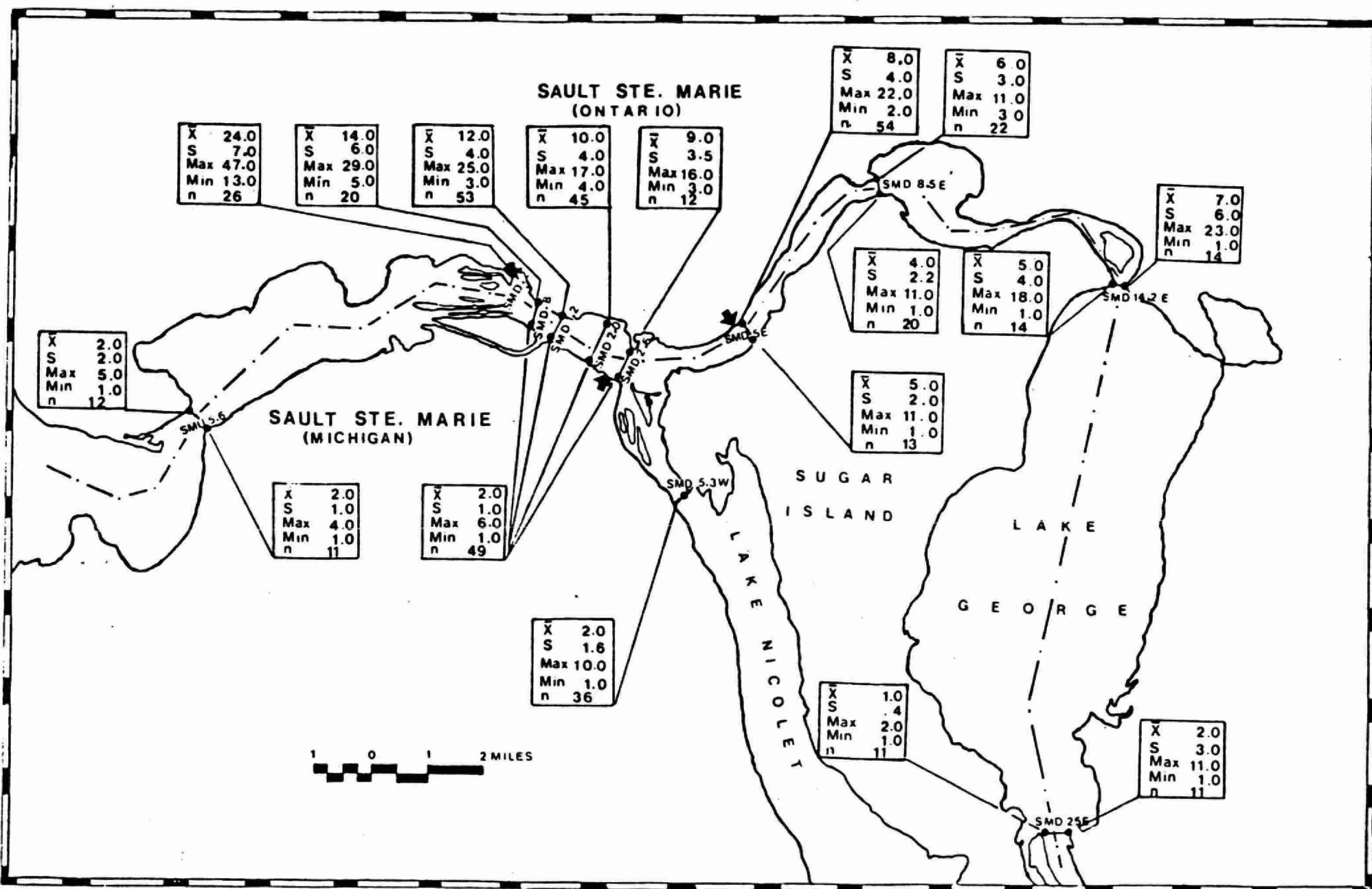


FIGURE 5: STATISTICAL SUMMARY OF PHENOL DISTRIBUTION - 1974 ($\mu\text{g/l}$)

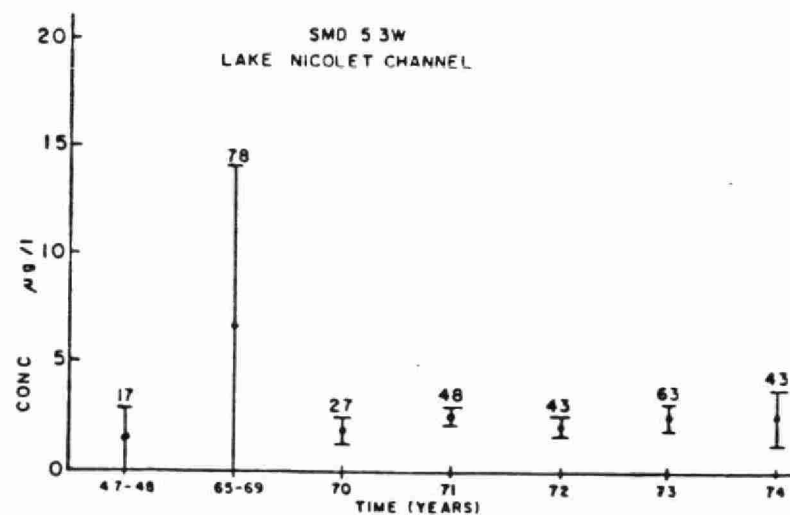
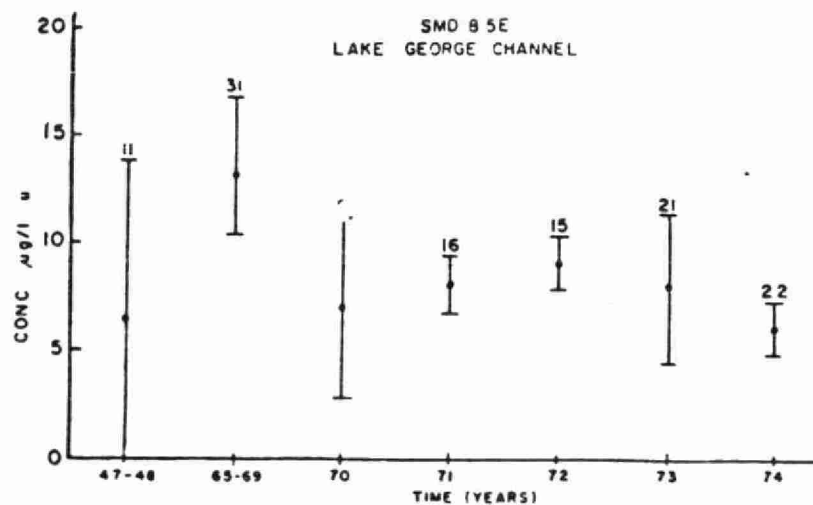
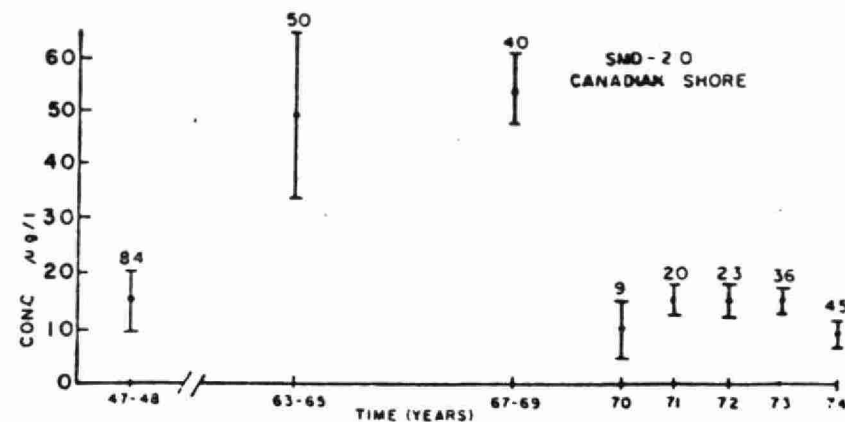
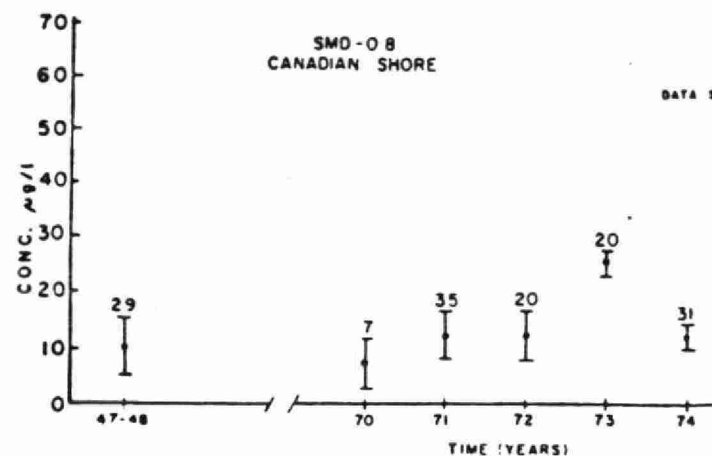


FIGURE 6: YEARLY TRENDS FOR PHENOL LEVELS

those observed during the previous years. This reduction is mainly attributed to the change in the type of coking coal used in Algoma Steel coke oven operations which may have produced lower levels of phenols upon distillation. Levels of phenols, however, were in non-compliance with the Water Quality Agreement objectives and Ministry criteria.

Ammonia

Ammonia exhibited a pattern similar to that of phenols. Average concentration along the Canadian shore declined from 0.4 mg N/l near the Algoma Steel outfall to 0.2 mg N/l at the beginning of the Lake George Channel (Figure 7). Levels in the channel reached a peak of 0.4 mg N/l just downstream from the Sault Ste. Marie STP which discharges ammonia at a rate of 700 kg/day. Ammonia levels were higher than the background levels (0.01 mg N/l) at the headwaters of the river. Average levels, did not violate the Ministry permissible criteria for drinking water. Along the U. S. shore, ammonia was comparable with background levels.

Whereas ammonia accounted for less than 5% of total nitrogen in the headwaters of the river, it constituted up to 65% and 40% of the total nitrogen downstream from the Algoma Steel main trunk sewer and the STP, respectively. The elevated ammonia levels exhibited no adverse effects on the oxygen balance in the river.

Cyanide

Cyanide attributable to Algoma Steel averaged 0.28 mg/l during 1974 near the Canadian shore just downstream from the main trunk sewer. Levels diminished rapidly to an average concentration of 0.06 mg/l near the Canadian shore at 1 km downstream from the Algoma Steel outfall (Fig. 8). Cyanide also follows the channel to the north of Sugar Island as evidenced by an average concentration of 0.03 mg/l. Along the U.S. shore, levels were comparable with those at the headwaters of the river (0.01 mg/l). In general, levels near the Algoma Steel outfall during 1973-74 were higher than those in the previous years mainly due to the prevailing low flows in recent years. Levels along the Canadian shore did not violate Ministry criteria for drinking water supply with the exception of an area extending to 300 m downstream from the outfall.

Heavy Metals

The distribution of filtered copper, zinc and total iron in the St. Marys River waters is illustrated in Fig. 9. No variation in filtered copper levels (1-2 μ g/l) along the U.S. and Canadian shores was observed. Levels of filtered zinc

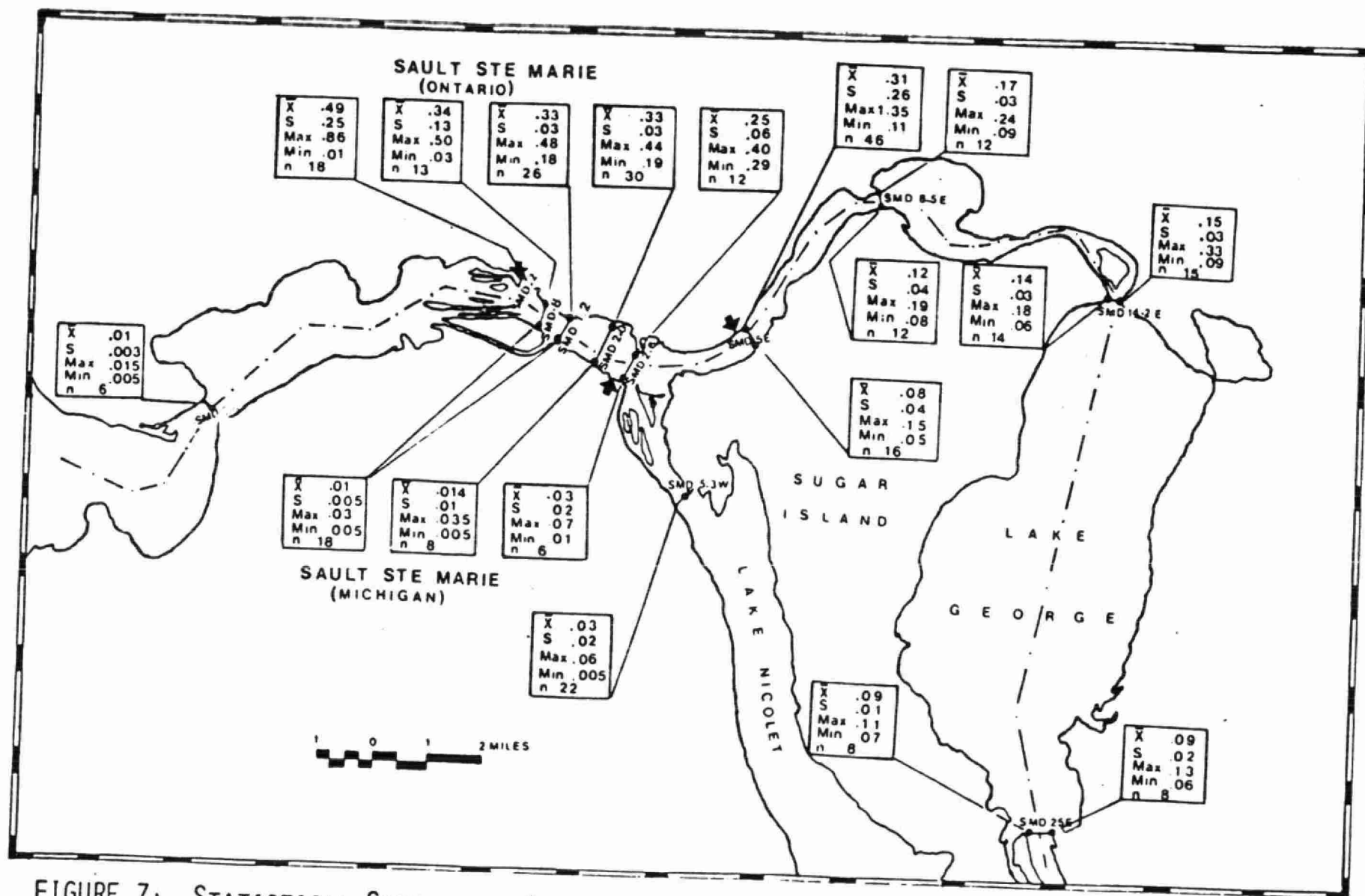


FIGURE 7: STATISTICAL SUMMARY OF AMMONIA DISTRIBUTION - 1974 (mg N/l)

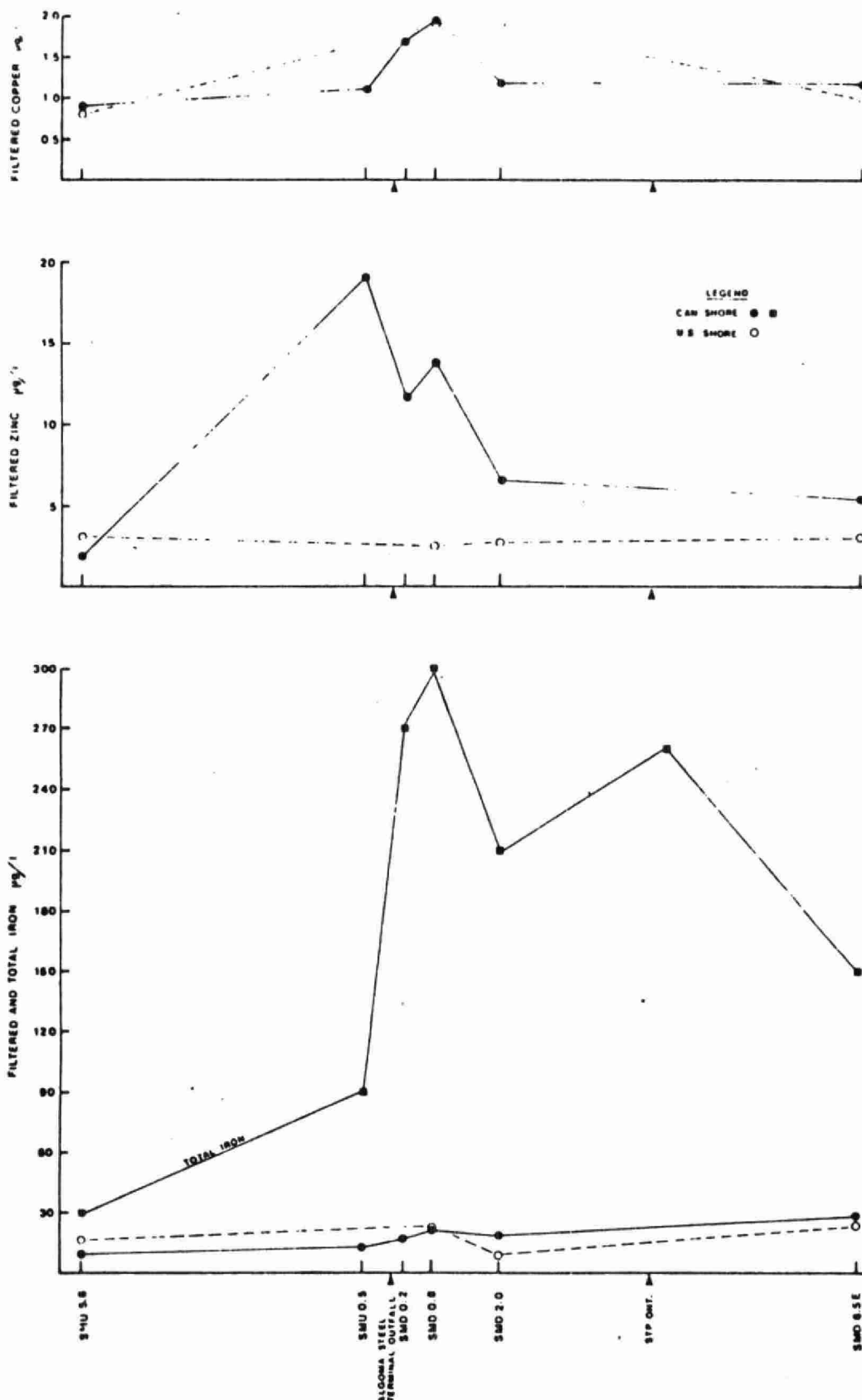


FIGURE 9: DISTRIBUTION OF HEAVY METALS
 Filtered Metals - CCIW Data
 Total Iron - MOE Data

along the Canadian shore exhibited a peak of 19 µg/l just downstream from the Algoma slip. Levels declined to 5 µg/l farther downstream and were comparable to background levels. Along the U.S. shore zinc levels of 5 µg/l were prevalent.

Total iron levels approached the Water Quality Agreement objective and Ministry criterion of 300 µg/l just downstream from the main trunk sewer. Farther downstream along the Canadian shore, iron levels ranged from 130-250 µg/l.

Yearly trends were examined for total iron levels downstream from Algoma Steel and in Lake George Channel (Figure 10) during the period 1970-74. Significant upward trends were found at 1.3 and 3 km downstream from Algoma Steel main trunk sewer. At the entrance of Little Lake George, iron concentrations did not exhibit significant changes at 95% confidence level.

Toxicity Predictions

From the above discussion, it is evident that the elevated levels of phenol, ammonia and cyanide constitute major water quality impairment in the river.

The toxicity of cyanides to fish has been reported in the literature. For example, one study found (4) that concentrations of free cyanide in excess of 0.025 mg/l were considered unsafe in the water of the Ohio River. Doudoroff (5) found that certain metals such as zinc and cadmium may complex with cyanide to increase lethality in fish. In addition to the direct effect of a given concentration of toxicant on fish, toxicity is influenced by such factors as temperature, alkalinity, pH, dissolved oxygen and hardness.

The combined toxic effect of phenols, ammonia, cyanide and heavy metals in the St. Marys River have an additive effect during their simultaneous presence. One way of measuring whether the combined amounts of these toxicants cause deterioration in the environment is through the following relationship (6):

$$\frac{C_a}{(TL_{50})_a} + \frac{C_b}{(TL_{50})_b} + \dots \leq 1.0$$

where:

C = the concentration of toxicants a, b, ..n in the receiving water;
TL₅₀ = the threshold concentration or median tolerance limit at which half the tested organisms will succumb over a given period of exposure such as 24, 48 or 96 hrs.

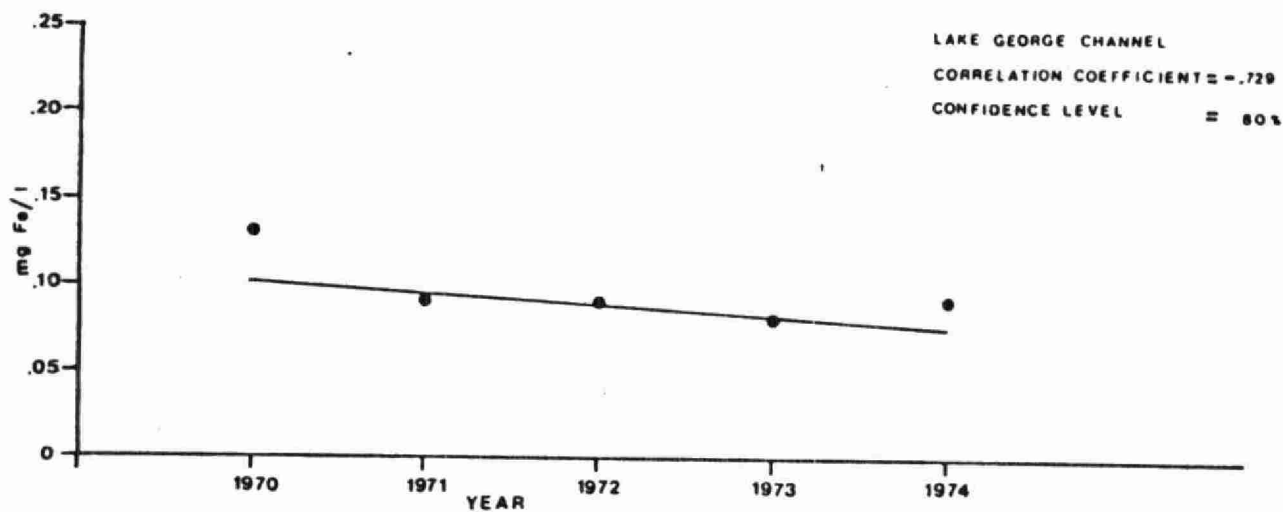
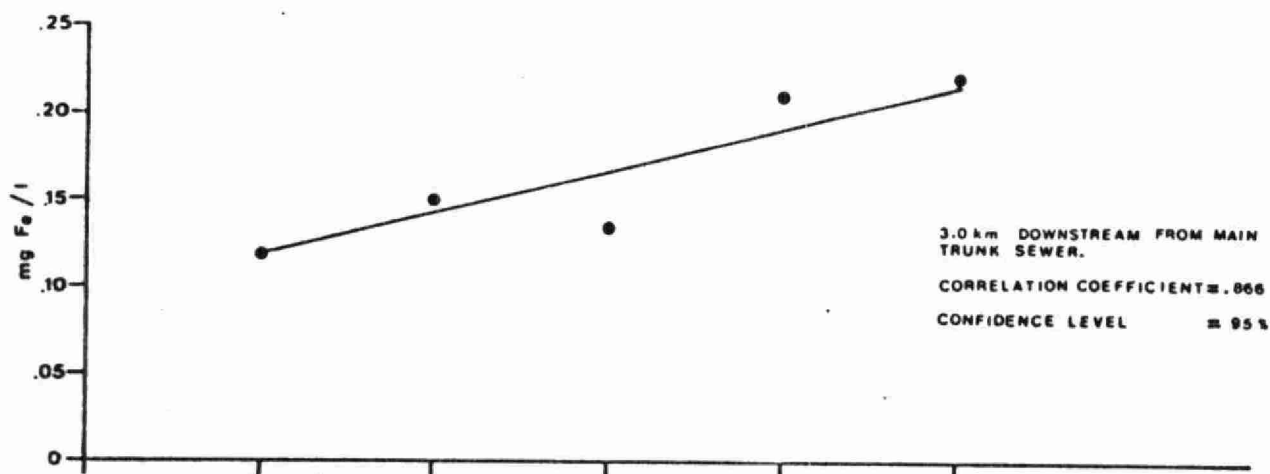
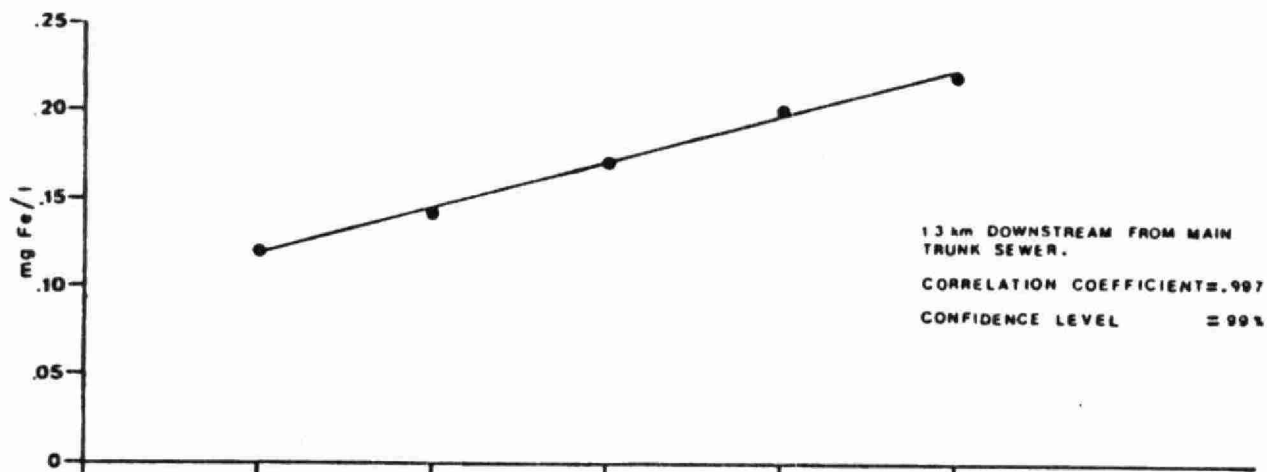


FIGURE 10: YEARLY TRENDS FOR TOTAL IRON CONCENTRATIONS
NEAR CANADIAN SHORE

A sum of 1.0 indicates that 50% of fish will die within the TL₅₀ exposure period. Long-term effects may be the mortality of the total population.

Lloyd and Jordan (7,8), however, found that 50% of fish died at an average sum of 0.7 and not 1.0. This may reflect a synergistic rather than a simple additive effect of the combined toxicants.

A method of graphical interpolation (6) was used to determine the 48 hr TL₅₀ for phenol, ammonia and cyanide in the river. To remove low, nonadditive concentrations from the above formula, any single fraction which has a value less than 0.2 was deleted from the calculations (9). Based on the maximum concentrations observed in the receiving water, it was found that the sum of the proportional toxicity was higher than 1.0 and 0.7 for a distance of 1.3 and 3 km, respectively, downstream from the main trunk sewer. Furthermore, the sum exceeded 0.7, based on average concentrations, for a distance of 100 m from the outfall. The lateral extent for the above zones was about 100 m from the Canadian shore.

It should be stressed that these toxicity predictions are not intended to replace bioassays, but are a tool for providing an order of magnitude estimate of the effects of pollutants on the river. The Ministry conducted static bioassays (unpublished-MOE 1976) for the main trunk sewer effluent using rainbow trout (spring spawn fry) as a test species. It was revealed that the effluent is toxic at a concentration of 2% (by volume) after an exposure time of 96 hr.

Bacterial Contamination

Total coliform, fecal coliform and fecal streptococci levels in the river are within the Water Quality Agreement objectives with the exception of periodically localized areas along the Canadian shore.

Yearly trends of bacterial parameters in the river are shown in Table 1. Total coliform levels determined by the MPN method during 1946-47 (1) were higher than those observed in the last decade (analysed by the Membrane Filter-MF-method). However, all bacterial parameters indicated elevated levels during 1973-74.

It is difficult to assess trends during the last decade, primarily due to the large variations between the minimum and maximum levels recorded (e.g. 30-2000 organisms/100 ml) in a given year, time of sampling, variation in media and techniques used in the analyses, and intermittent discharges from storm sewers.

TABLE 1

YEARLY TRENDS OF BACTERIAL PARAMETERS IN THE LOWER ST. MARYS RIVER

PERCENTAGE OF STATIONS IN RANGE

Year	Canadian Shore			International Boundary			U.S. Shore		
	<100	100-1000	>1000	<100	100-1000	>1000	<100	100-1000	>1000
<u>Total Coliforms</u>									
1946-48	-	33	67	-	50	50	36	57	7
1969	55	36	9	86	-	14	80	10	10
1970	64	36	-	88	12	-	90	10	-
1971	22	67	11	50	50	-	43	57	-
1972	20	80	-	67	33	-	100	-	-
1973	-	77	23	27	55	18	39	61	-
1974	5	84	11	68	26	6	76	20	4
	<10	10-100	>100	<10	10-100	>100	<10	10-100	>100
<u>Fecal Coliforms</u>									
1970	9	91	-	62	38	-	33	67	-
1971	44	56	-	75	25	-	57	43	-
1972	80	20	-	100	-	-	100	-	-
1973	3	81	16	42	58	-	72	28	-
1974	12	78	10	53	47	-	76	24	-
	<10	10-20	>20	<10	10-20	>20	<10	10-20	>20
<u>Fecal Streptococci</u>									
1970	45	45	10	78	22	-	92	8	-
1971	78	11	11	75	25	-	100	-	-
1972	80	20	-	100	-	-	100	-	-
1973	34	22	44	66	17	17	81	19	-
1974	70	18	12	93	7	-	97	3	-

1946-48 Data Analysed by MPN Method

1969-74 Data Analysed by Membrane Filter Method

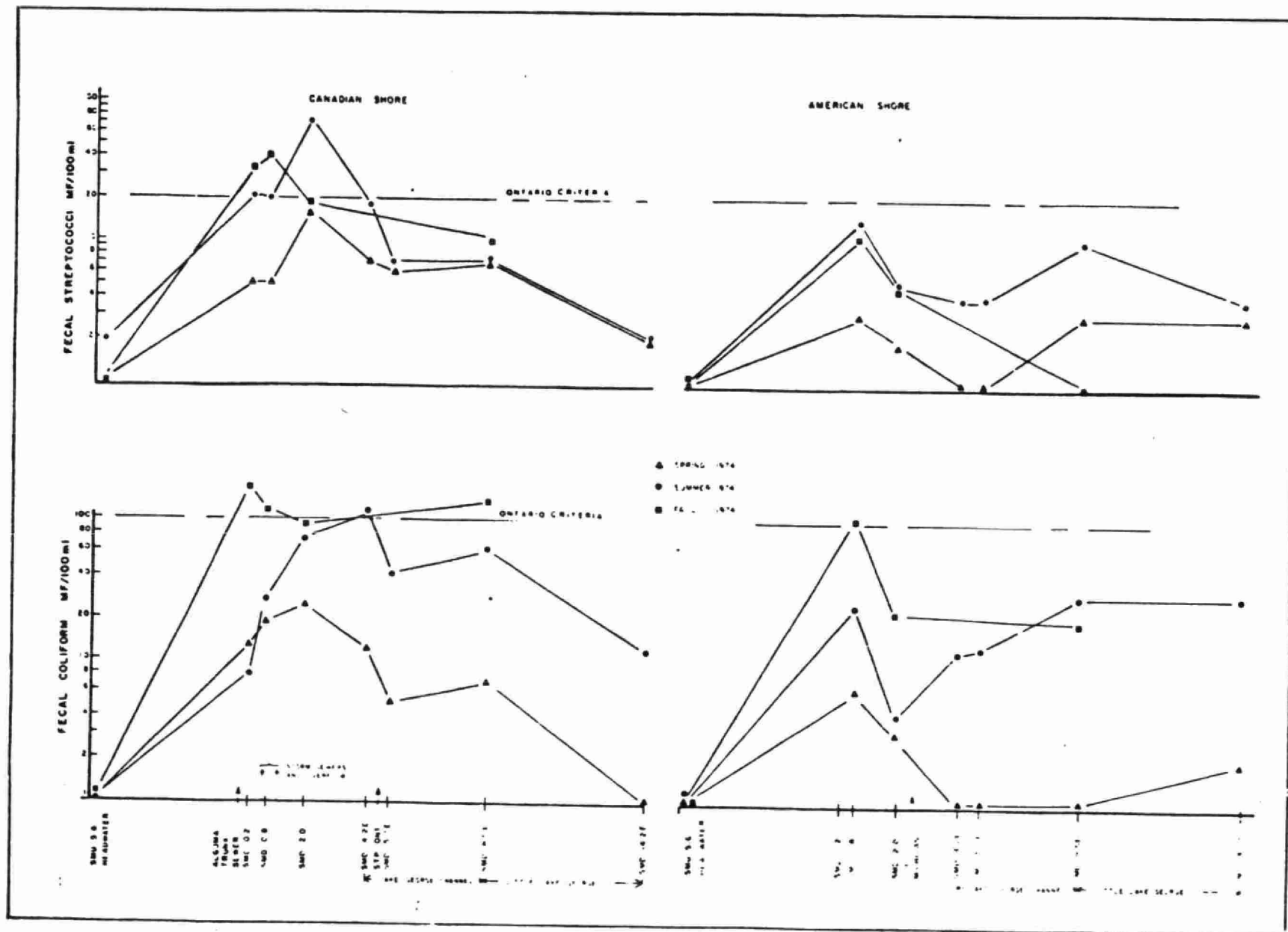


FIGURE 11: DISTRIBUTION OF FECAL COLIFORMS AND FECAL STREPTOCOCCI IN ST. MARYS RIVER-1974

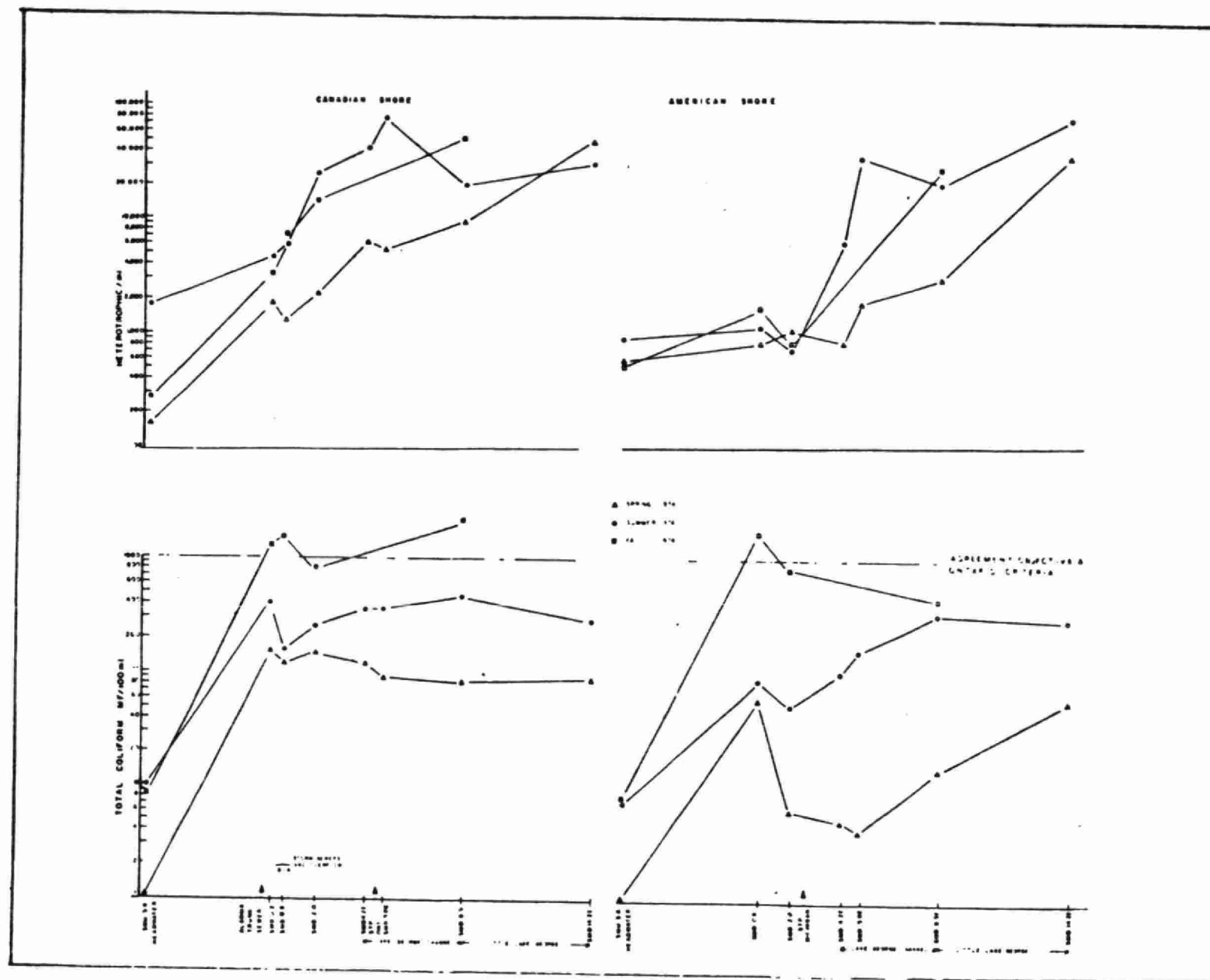


FIGURE 12: DISTRIBUTION OF TOTAL COLIFORMS AND HETEROTROPHS IN ST. MARYS RIVER - 1974

Seasonal variations in levels of total coliform, fecal coliform and fecal streptococci are illustrated in Figures 11 and 12 (Spring-May and June; Summer-July and August; Fall-September and October). Apparent peaks in total coliform, fecal coliform and fecal streptococci levels during summer 1973 and fall 1974 were noticed along the Canadian shore in the immediate vicinity of the storm sewers for the city of Sault Ste. Marie, Ontario and downstream from the STP outfall in Lake George Channel.

The fecal coliform to fecal streptococci ratio near the urban areas of Sault Ste. Marie, Michigan and Ontario during the summer was less than 0.7 indicating storm water sources of contamination (10). Farther downstream, in the vicinity of the STP, the ratio changed to values higher than 4 indicating sewage contamination. Along the U. S. shore and in Lake Nicolet Channel, levels of all bacterial parameters were within the Water Quality Agreement objectives confirming the low levels U.S. waste inputs and the confinement of waste discharges from the Canadian shore to the north side of Sugar Island.

Pseudomonas aeruginosa counts in the river during 1974 indicated serious health hazard problems along the city of Sault Ste. Marie, Ontario, waterfront.

P. aeruginosa is pathogenic and known to cause ear, nose and throat infections in swimmers. It utilizes a wide variety of organic compounds and quaternary ammonium compounds. Sewage and storm drainage represent the major sources of *P. aeruginosa* appearing in surface waters. Hoadley (11) indicated that populations of 1-10 *P. aeruginosa* organisms/100 ml may be expected in streams with low, but definite levels of contamination. Levels of *P. aeruginosa* (20-30 organisms/100 ml) in the vicinity of storm sewers of Sault Ste. Marie, Ontario, exceeded the above levels and the background levels (4 organisms/100 ml). Levels declined farther downstream but reached another peak (15 organisms/ 100 ml) in the Lake George Channel downstream from the STP.

Enrichment

Phosphorus levels in the river were generally comparable with background (0.011 mg P/l). In zones of high current velocities such as at the beginning of the Lake George Channel, elevated phosphorus levels of 0.040 mg P/l are thought to be associated with suspended sediments. During 1974, levels downstream from the STP were higher than those observed in 1973. At the entrance of Little Lake George, phosphorus declined to background levels. No increase in biomass occurs as reflected by chlorophyll *a* levels at the river mouth (1.0 µg/l) which were similar to those at the headwaters.

The heterotrophic bacterial counts across the Lake George Channel indicated an abundance of decomposing organic matter downstream from the Ontario sources. Levels as high as 100,000 counts/ml were observed in the channel and at the outlet of Lake George.

Because of the shallow nature of Lake George and low current velocities, precipitation of silts is accelerated. Thus, the eutrophic status of the lake is natural in origin and probably is not significantly affected by upstream waste inputs.

SEDIMENTS

Physical Characteristics

The St. Marys River sediments upstream from the industrial discharges were composed of clean sands interspersed with gravel patches in the faster flowing portions of the river. An alteration in sediment composition was detected in an embayment located between the Algoma slip and a newly constructed landfill designated as a disposal site for slag pickle liquor and alkaline wastes from Algoma operations. The sediments in this embayment were composed chiefly of silt interspersed with patches of sand. The origin of the silt may be accounted for in part by the sheltered characteristics of the bay and in part by possible erosion from the landfill.

In the immediate vicinity of the Algoma slip outfalls, the sediments were characterized by silty clays. From this site, a narrow band of silty sands extended along the Canadian shore downstream from the Algoma slip for a distance of approximately 3 km.

Sediments in the U.S. portion of the river were characterized by clean sands with the exception of the St. Marys Rapids area where gravel predominated. Sediment composition in the section of the river between the rapids and the entrance to Lake George appeared to be strongly related to flow velocities and depth contours both of which varied greatly in the area. The patchy sediment pattern which resulted largely obscured the effects of effluents on sediment composition.

In the Lake George Channel and downstream from the Sault Ste. Marie STP, predominantly silty sediments were found to extend for a distance of 0.8 km. Farther downstream and as far as Little Lake George, the pattern was characterized by silty sands. Sands predominated again at the entrance to Lake George.

The sediment composition in Lake Nicolet and Lake George was characterized by clays in the upper portions and clays with sand mixtures in the southern reaches.

Sediment Chemistry

This section describes the distribution of heavy metals, organic and inorganic contaminants and nutrients in the sediments of the St. Marys River and delineates zones of sediment impairment.

In assessing the significance of contaminants in sediments, reference was made to preliminary guidelines for the evaluation of Great Lakes sediments that have been developed by the Environmental Protection Agency (EPA) Region V(12).

It was felt that the sediment classification followed in these guidelines, as heavily polluted, moderately polluted and non-polluted, should best reflect the extent of anthropogenic influence. Reference was also made to the Ministry guidelines for dredging and open water disposal (13).

Heavy Metals

The sediments upstream from the industrial complex were uncontaminated by heavy metals. Concentrations of zinc and iron in Whitefish Bay were 10 mg/kg and 0.5%, respectively. Both values, which will be referred to later in this report as background levels, are well within the 90 mg/kg and 1.7% EPA interim guidelines for non-polluted sediments.

Severe contamination of sediments by heavy metals was localized and largely confined to the Canadian shore.

Preliminary EPA guidelines (1975) for zinc in Great Lakes sediments are as follows:

Non-polluted <90 mg/kg
Moderately polluted 90-200 mg/kg
Heavily polluted >200 mg/kg

Highest levels of zinc in the study area were observed in the bay adjoining the Algoma landfill (1110 mg/kg), in the Algoma slip (680 mg/kg) and in the embayment near the entrance to Little Lake George (550 mg/kg).

The distribution of zinc in sediments downstream from the main trunk sewer of Algoma Steel suggests that zinc discharged at this location is bound to fine grain materials which remain in suspension in the fast moving portion of the river and deposit some distance away from the source in the sheltered embayments.

Immediately downstream from the trunk sewer, in an area of high flow velocity, zinc contamination was moderate (average concentration 120 mg/kg). This zone extended for a distance

of 3 km along a narrow band confined to the Canadian shore. Downstream from this zone, zinc began to deposit in large quantities in a large sheltered embayment (Figure 13) where the average concentration was 375 mg/kg with a maximum of 500 mg/kg.

Transboundary movement of zinc was evident at the inflow to Lake Nicolet and in the Lake George Channel where moderately high values were found. Levels of zinc returned to near background in Lake George and Lake Nicolet.

Preliminary EPA guidelines (1975) for iron in Great Lakes sediments are as follows:

- Non-polluted <1.7%
- Moderately polluted 1.7-2.5%
- Heavily polluted >2.5%

The general distribution of iron was similar to that of zinc, showing transboundary movement in the inflow to Lake Nicolet and in Lake George Channel (Figure 14). Background levels were recorded in Lake Nicolet and Lake George.

Highly polluted sediments were found in the embayment adjacent to the Algoma landfill, in the Algoma slip and downstream from the main trunk sewer as far as the entrance to Little Lake George and Lake Nicolet.

Most severe iron contamination was detected downstream from the trunk sewer where the average iron concentration was 34% with a maximum of 45% by weight. This zone was confined to a narrow band along the Canadian shore for a distance of 3 km. This observation suggests that unlike zinc, iron discharged through the trunk sewer is bound to coarse-grained materials which deposit relatively close to the source in spite of high flow velocities.

Heavily contaminated sediments were found also in sheltered portions of the river. All three major embayments in the area were characterized by average iron concentrations of 8% by weight.

Inorganic Contaminants

Preliminary EPA guidelines (1975) for cyanide in Great Lakes sediments are as follows:

- Non-polluted <.10 mg/kg
- Moderately polluted .10-.25 mg/kg
- Heavily polluted >.25 mg/kg

CONC. mg/kg	SAMPLE SIZE	RANGE mg/kg	MEAN mg/kg	STD DEV
<60	25	MIN. 9.4 MAX. 59	37	215
60-199	17	MIN. 61 MAX. 190	107	242
>199	10	MIN. 200 MAX. 1100	477	2264



<60

25

MIN. 9.4
MAX. 59

37

215



60-199

17

MIN. 61
MAX. 190

107

242



>199

10

MIN. 200
MAX. 1100

477

2264

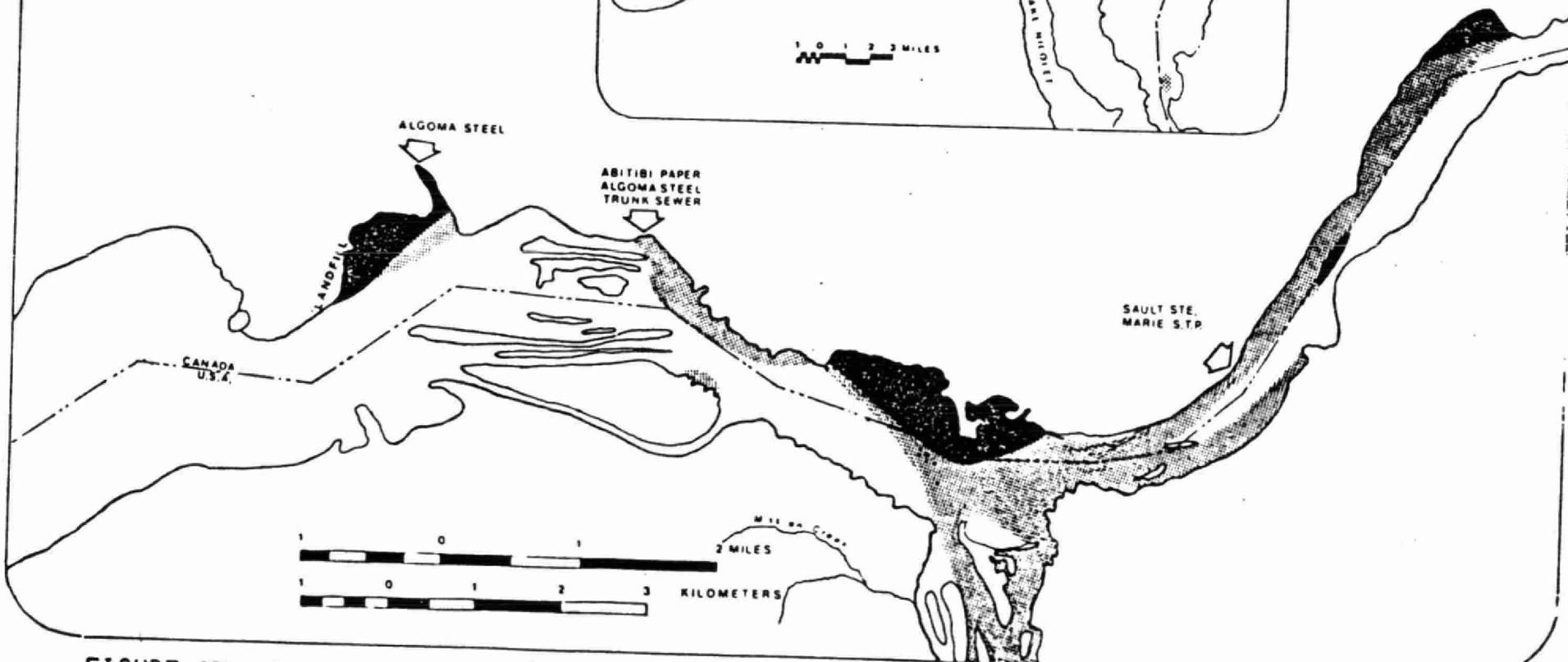
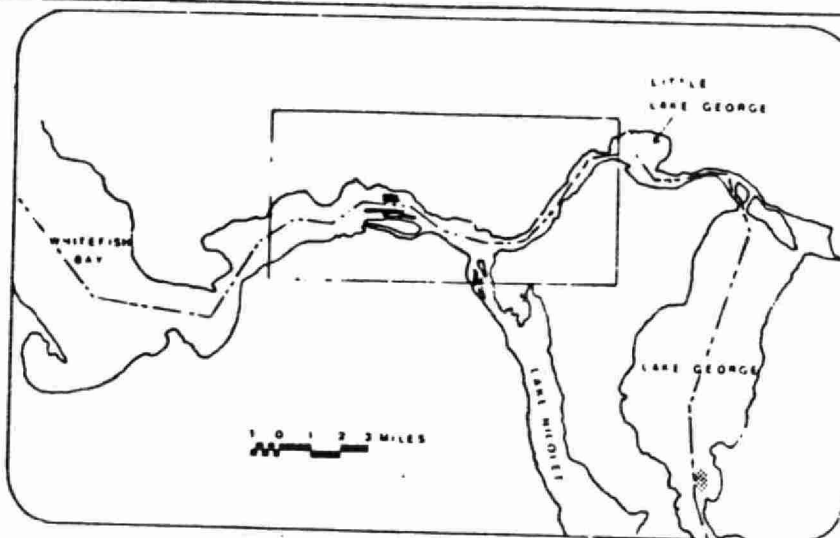


FIGURE 13: DISTRIBUTION OF ZINC IN ST. MARYS RIVER SEDIMENTS

CONC. %	SAMPLE SIZE	RANGE %	MEAN %	STD DEV
------------	----------------	------------	-----------	------------

○	<2.6	30	MIN. 0.39 MAX. 2.5	1.2 ±0.60
○	2.6-5.0	7	MIN. 2.7 MAX. 4.6	3.5 ±0.57
●	5.0-15	10	MIN. 5.0 MAX. 11	8.1 ±2.0
●	>15	4	MIN. 22 MAX. 45	34 ±10

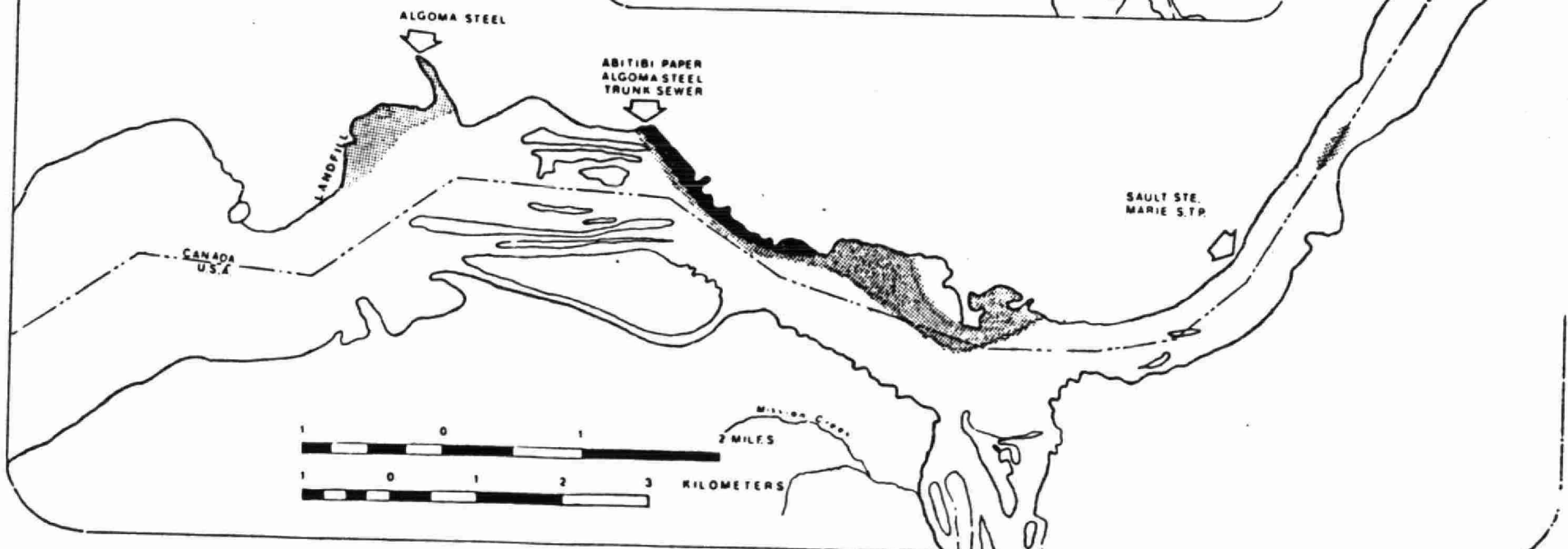
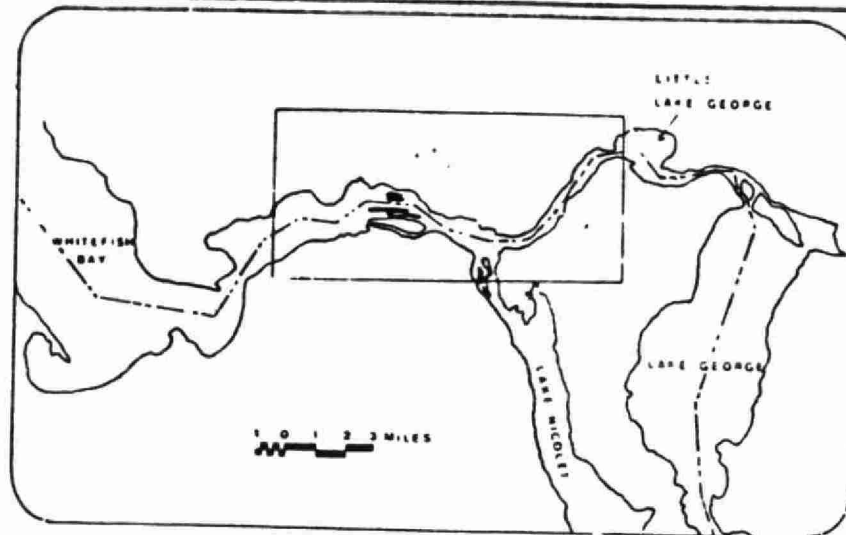


FIGURE 14: DISTRIBUTION OF IRON IN ST. MARYS RIVER SEDIMENTS.

The highest cyanide levels in the area were found downstream from the trunk sewer in a narrow band of sediments along the Canadian shore. Average concentration of cyanide in this zone was 12 mg/kg with a maximum of 14 mg/kg (Figure 15).

Elevated cyanide levels were also found in the Algoma slip (7.3 mg/kg); in an embayment 3 km downstream from the trunk sewer (4.8 mg/kg) and near the entrance to Little Lake George (2.8 mg/kg). Transboundary movement of this contaminant was minimal.

Organic Contaminants (Oil and Grease)

Preliminary EPA guidelines (1975) for oil and grease compounds (ether solubles) are as follows:

- Non-polluted <1000 mg/kg
- Moderately polluted 1000-2000 mg/kg
- Heavily polluted >2000 mg/kg

The background levels for the area were 600 mg/kg of ether soluble substances.

Almost the entire Canadian side of the river was highly contaminated by oil and grease downstream from the Algoma complex as far as the entrance to Little Lake George (Figure 16). Highest levels of ether soluble compounds were detected in a large embayment 3 km downstream from the trunk sewer (7000 mg/kg), in the Algoma slip (8200 mg/kg) and in an embayment at the entrance to Little Lake George (9200 mg/kg). These levels exceeded Ministry guidelines for dredging (1500 mg/kg). Transboundary movement of oil and grease in the river was minimal. Small localized areas of impairment detected along the American shore appeared to have originated on the U.S. side of the river. No evidence of contamination by oil and grease was found in Lake Nicolet or downstream from the entrance to Little Lake George.

High phenol levels in sediments (13 mg/kg) were observed for a distance of 5 km downstream from the Algoma Steel main trunk sewer outfall. After recovering to background levels of 3 mg/kg, the phenol concentrations rose again to 6 mg/kg downstream from the STP and persisted to the entrance of Lake George. No guideline for phenols in sediments is available.

Wood particles in sediments upstream from the industrial discharges were found in isolated patches which could be attributed to former log booming operations in the area. Immediately downstream from Abitibi Paper Co. the sediments were composed entirely of wood chips (Figure 17). The wood accumulation was largely confined to the Canadian shore of

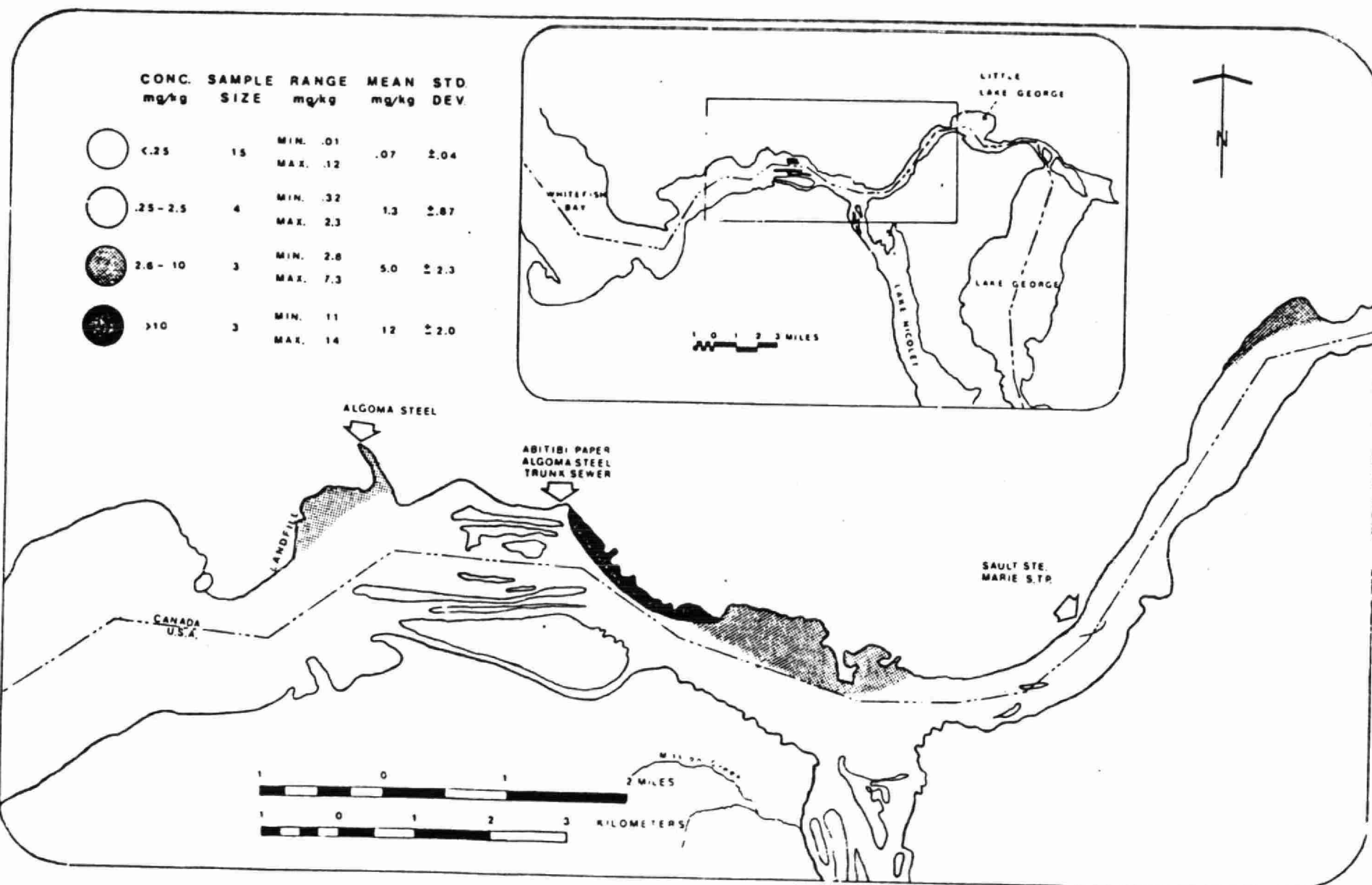


FIGURE 15: DISTRIBUTION OF CYANIDE IN ST. MARYS RIVER SEDIMENTS

CONC. mg/kg	SAMPLE SIZE	RANGE mg/kg	MEAN mg/kg	STD DEV
○ <1000	19	MIN. 44 MAX. 800	380	±250
○ 1000-2000	4	MIN. 1000 MAX. 1700	1400	±330
● 2000-5000	6	MIN. 2000 MAX. 3800	3200	±790
● >5000	9	MIN. 8500 MAX. 19000	11220	±4300

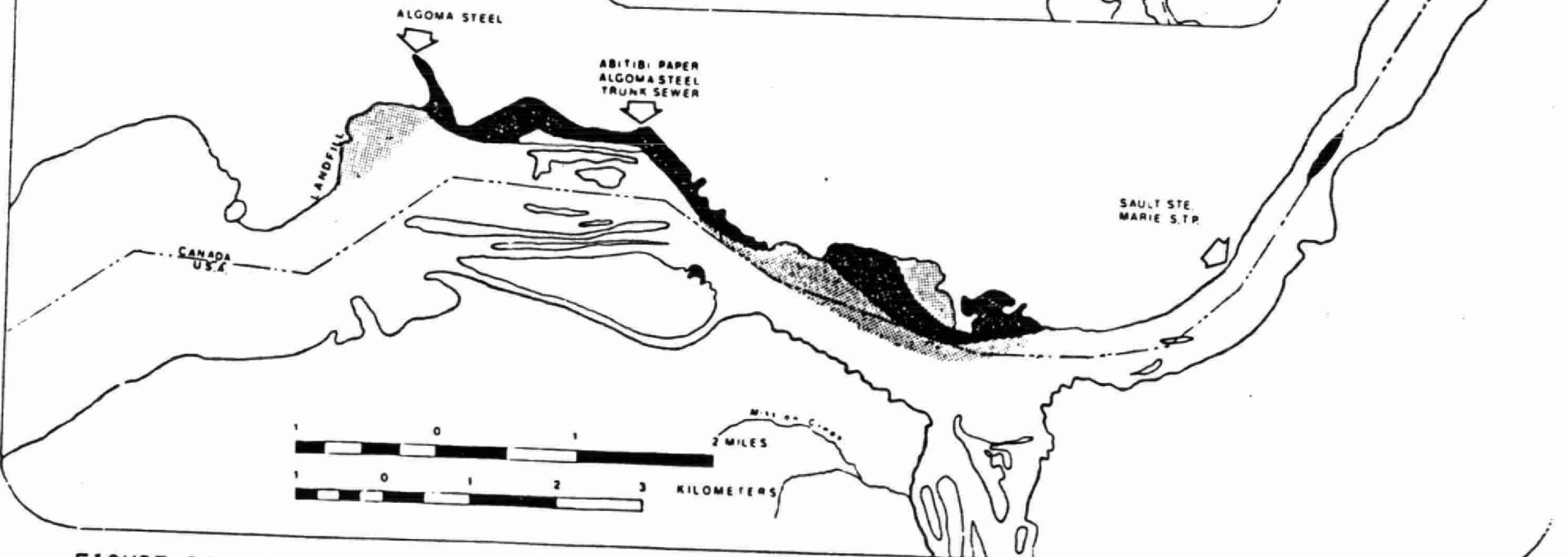
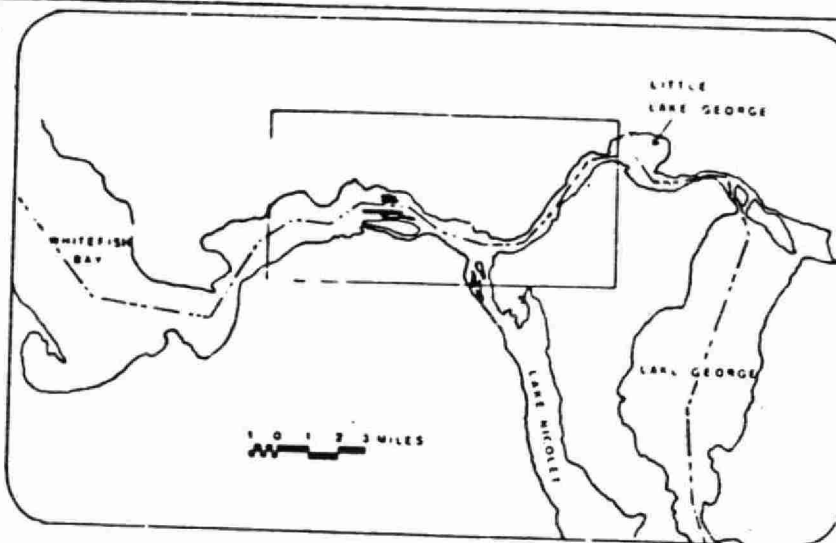
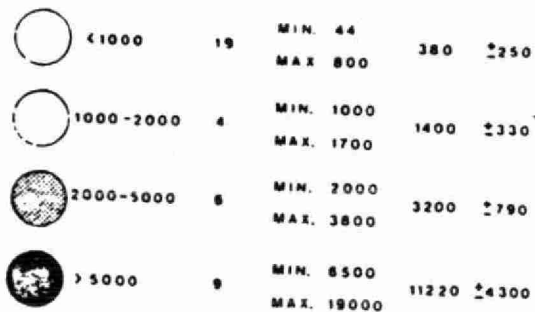


FIGURE 16: DISTRIBUTION OF OIL AND GREASE IN ST. MARYS RIVER SEDIMENTS

CONC. %	SAMPLE SIZE	RANGE %	MEAN %	STD DEV
0-trace	88	MIN. 0 MAX. trace		
1-33	22	MIN. 1 MAX. 30	14.1	± 7.7
34-66	6	MIN. 40 MAX. 50	47.5	± 4.2
67-100	3	MIN. 100 MAX. 100	100	± 0

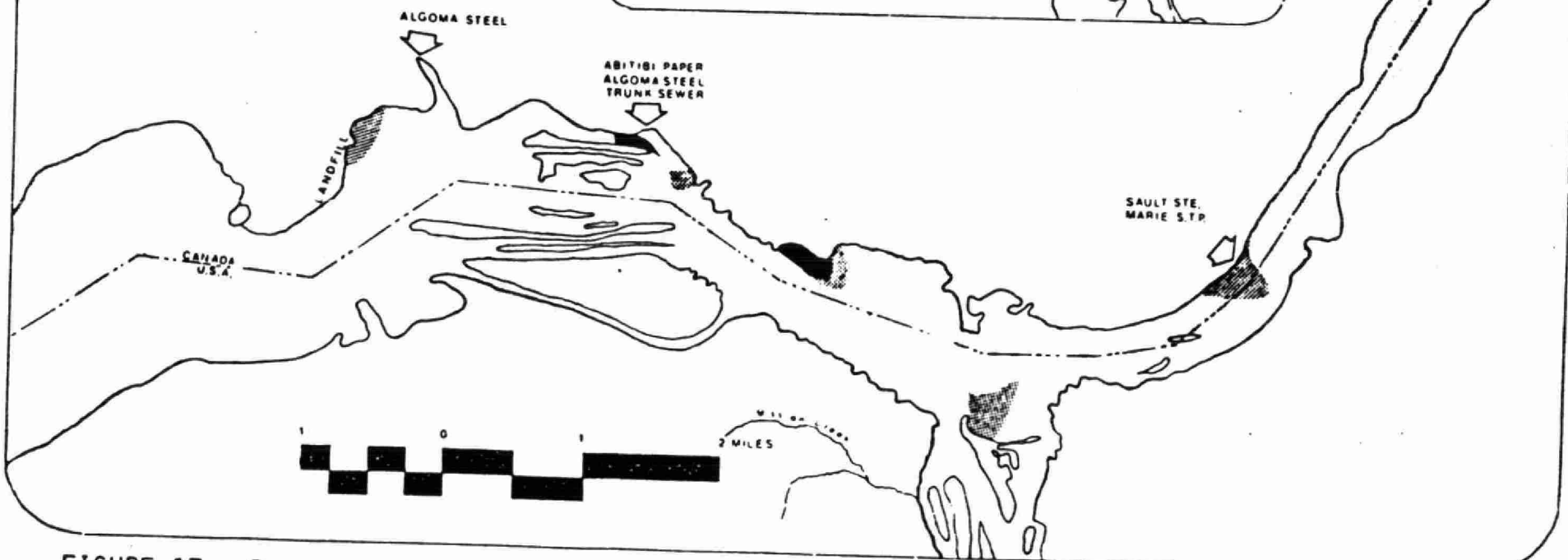
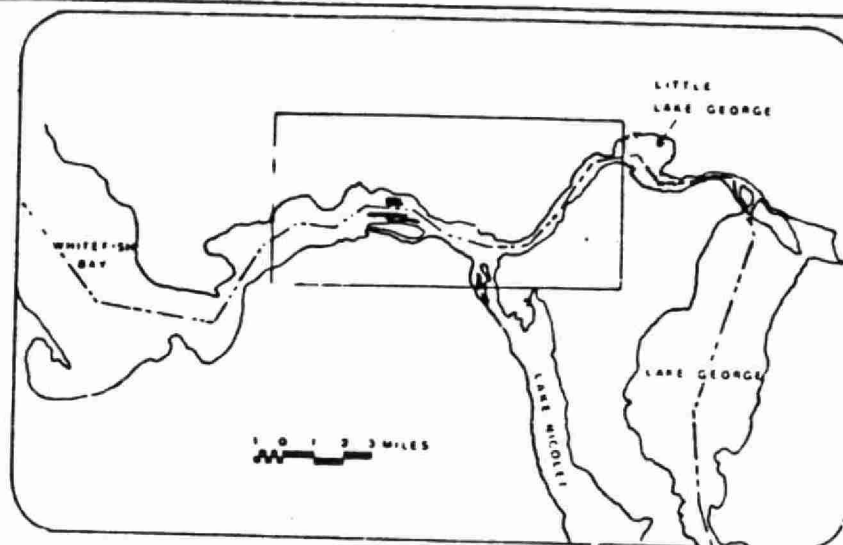
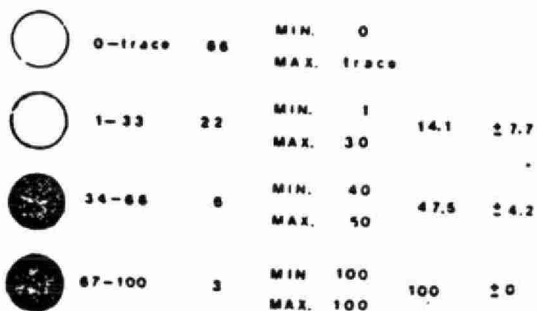


FIGURE 17: DISTRIBUTION OF WOOD FIBRE IN ST. MARYS RIVER SEDIMENTS

the river although some transboundary movement was apparent. Downstream from the zone of deposition, wood distribution was patchy, never exceeding 20% of the sediment volume.

Nutrients

Preliminary EPA guidelines (1975) for total phosphorus and nitrogen in Great Lakes sediments are as follows:

	<u>Phosphorus</u>	<u>Nitrogen</u>
Non-polluted	<.42 mg/g	<1.0 mg/g
Moderately polluted	.42-.65 mg/g	1.0-2.0 mg/g
Heavily polluted	>.65 mg/g	>2.0 mg/g

Nutrient levels exceeded the above guidelines in the slow moving portions of the river, especially in embayments where fine-grained materials are deposited. The distribution of phosphorus and nitrogen in the sediments (Figures 18 and 19) did not exhibit a clear relationship to point sources entering the river although some response to the Sault Ste. Marie STP discharge was evident as reflected by elevated levels downstream from the outfall. In general, total phosphorus levels throughout the river were within Ministry guidelines (1 mg/g) whereas nitrogen exceeded the guidelines (2 mg/g) in Lake George Channel.

Nitrogen levels ranged from 1.2 mg/g-7.2 mg/g throughout most of the Lake George Channel dropping to moderate levels (average 1.2 mg/g) in Lake Nicolet and Lake George. Phosphorus levels of 0.76 mg/g were recorded in two embayments which exhibited elevated levels of all other chemical variables measured. Moderately high phosphorus levels were recorded in portions of the Lake George Channel dropping to background levels (0.3 mg/g) in Lake Nicolet and Lake George.

BENTHIC FAUNA EVALUATION

This section presents the effect of contaminants such as cyanide, heavy metals, oils, phenols and nutrients on the distribution of the benthic fauna in the St. Marys River. Owing to the great variability in substrate types, water depth, vegetation cover and time of sampling, it was not possible to report on the findings at much more than a qualitative level. Quantitative interpretation was largely restricted to reporting classes of species abundance and diversity of the macroinvertebrates. Abundance classes were chosen on a logarithmic scale and species diversity was determined according to the modification of Lloyd, Zar and Karr (14). Distribution of zoobenthos in the St. Marys River sediments is illustrated in Figure 20.

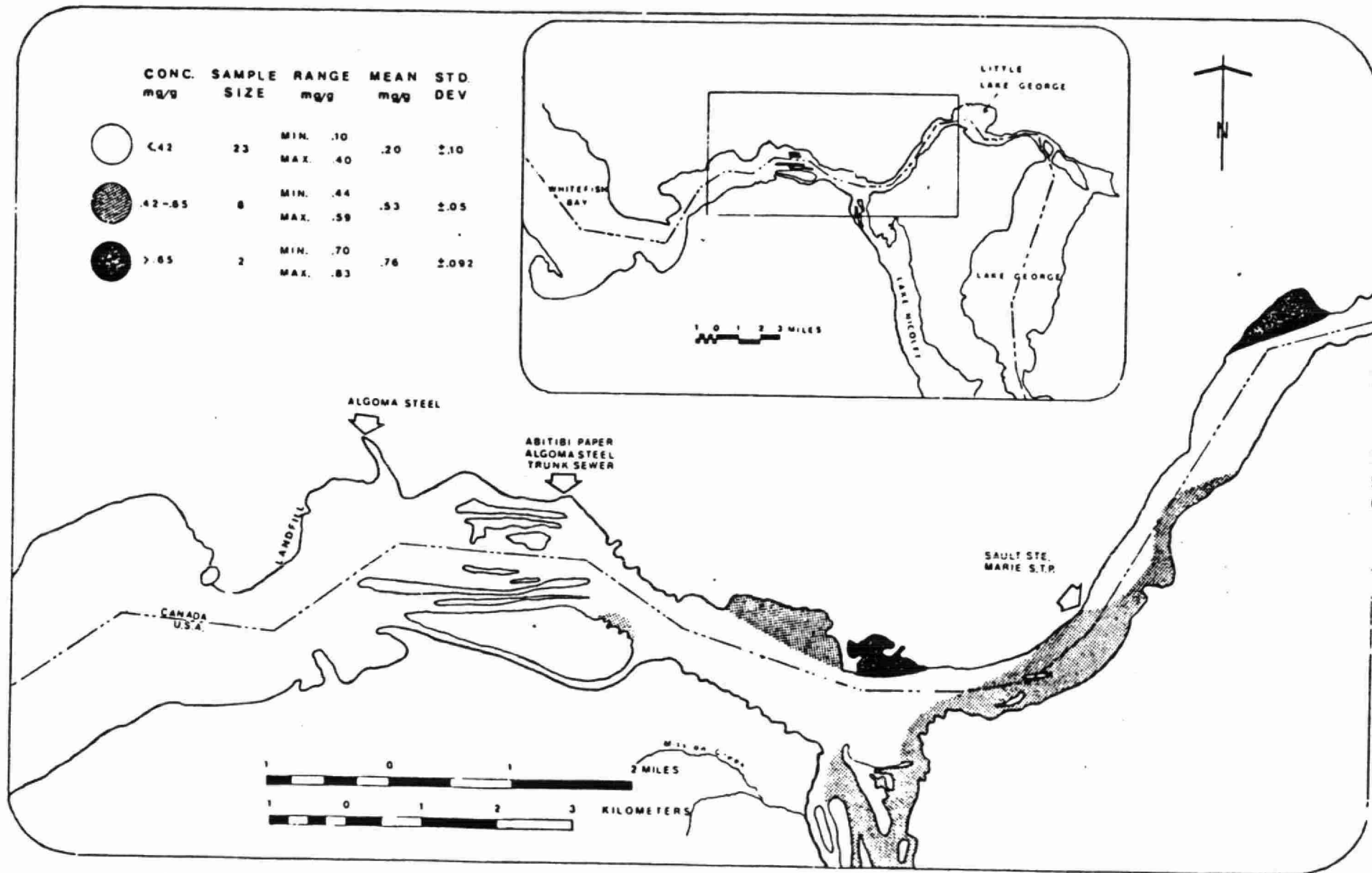


FIGURE 18: DISTRIBUTION OF TOTAL PHOSPHORUS IN ST. MARYS RIVER SEDIMENTS

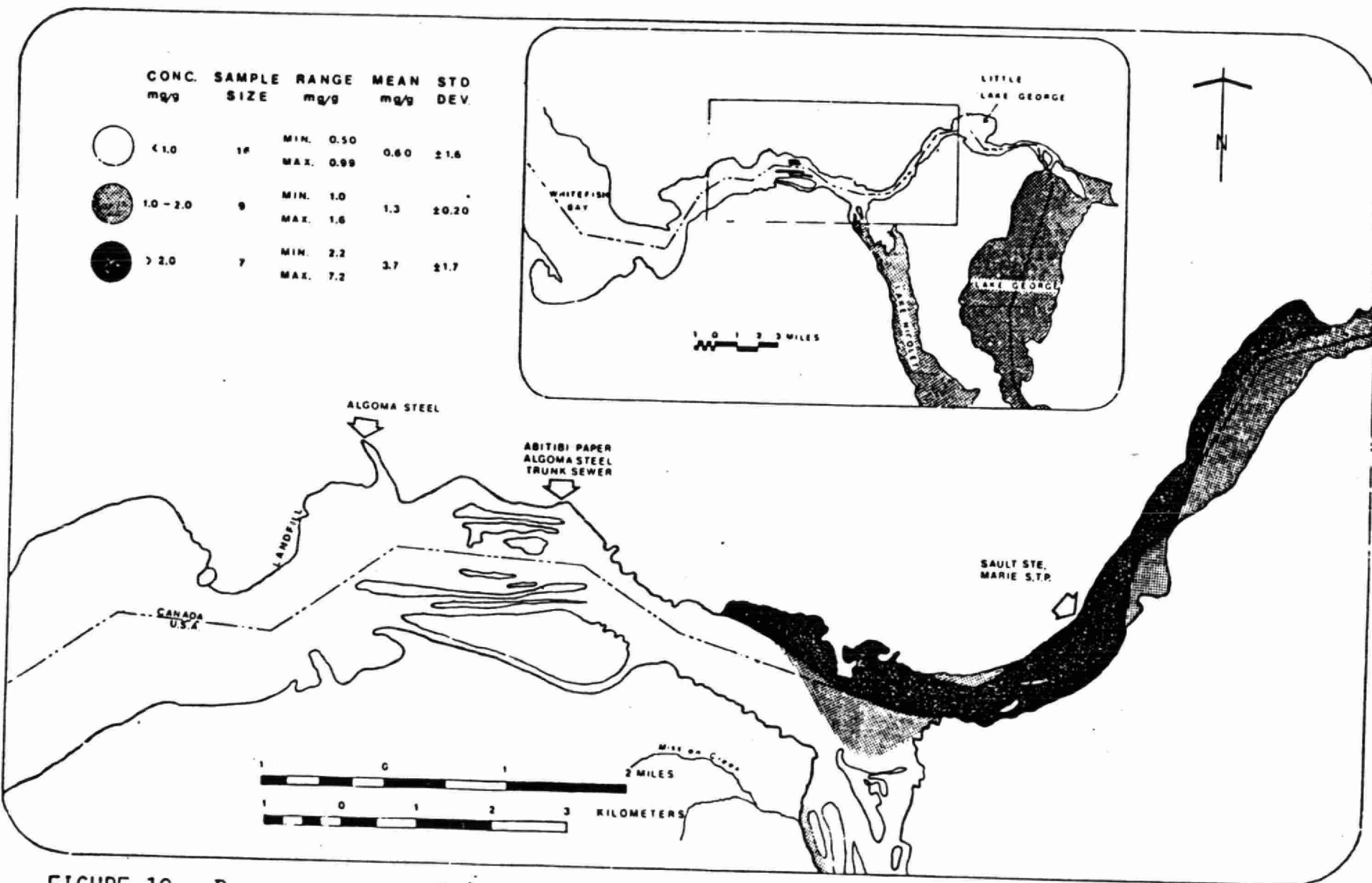


FIGURE 19: DISTRIBUTION OF TOTAL KJELDAHL NITROGEN IN ST. MARYS RIVER SEDIMENTS

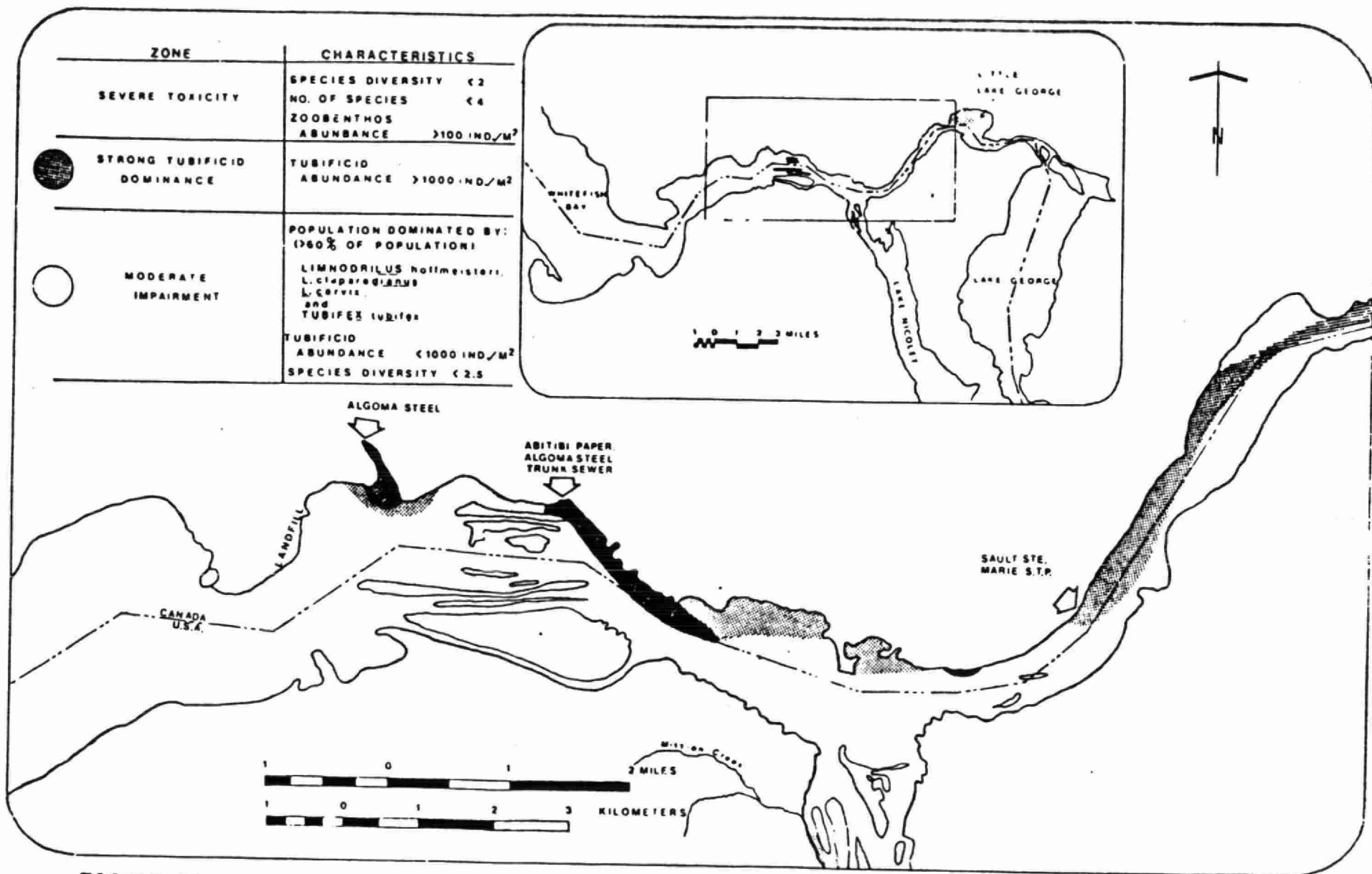


FIGURE 20: DISTRIBUTION OF ZOOBENTHOS IN ST. MARYS RIVER SEDIMENTS

Benthic Community Upstream From Industrial Discharges

The macroinvertebrate community was characterized by the presence of clean water species many of which commonly occur in the oligotrophic waters of lake Superior. High species diversity characterized the benthic community which was composed of a total of 38 species. Oligochaetes were found in low numbers, and were represented by *Peloscolex ferox*, *Aulodrilus americanus*, *A. limnobius*, *A. pluriseta*, *Potamothrinx moldaviensis* and *P. vejdoskyi*. With the exception of *Peloscolex ferox*, none of the oligochaete species showed strong dominance as is often the case in areas of impaired water quality.

Amphipods and isopods were common at the control station (headwaters) and were represented by all four genera occurring in the study area; *Gammarus*, *Hyalella azteca*, *Asellus* and *Lirceus*. Snails were also common, especially in the shallow embayment areas where clean water forms such as *Amnicola*, *Valvata* and *Helisoma* predominated. All three genera of mayflies were present in this section, *Hexagenia*, *Ephemera* and *Caenis* together with two genera of caddisflies, *Limnophilus* and *Hydropsyche*.

Benthic Community Downstream from Algoma Steel Slip

Severe disruption of the benthic community was detected in the Algoma slip. Downstream from this area, the benthic impairment was less acute and the disrupted zone confined to a narrow band approximately 300 m wide extending along the Canadian shore. Recovery of the benthic community was not complete 2 km downstream from the Algoma slip at which point an additional industrial discharge is introduced.

No abnormal conditions were detected in the benthic fauna surveyed on the American side of the river.

Zone of Severe Toxicity

The structure of the macroinvertebrate community in the Algoma slip was found to be severely disrupted. The fauna composition was restricted to midges and three species of oligochaetes, *Limnodrilus hoffmeisteri*, *Peloscolex ferox* and *Potamothrinx vejdoskyi*, all of which were present at the extremely low densities of less than 40 individuals/m². The direct toxicity of iron, zinc, cyanide, ether soluble and phenolic compounds accumulated in the sediments together with contaminants in the water column are thought to severely restrict the survival of most macroinvertebrate species in this zone and drastically reduce the abundance of individuals capable of surviving.

It is not possible at this time to isolate the contribution of each of the toxic compounds to the overall toxic effect. It is felt, however, that a major reason for the impoverished benthic fauna in the Algoma slip is likely the severe contamination of the sediments by oil. In addition, the high levels of zinc and cyanide appear to be a serious cause for concern especially since the toxicity of these compounds is synergistic.

Zone of Tubificid Dominance

Adjacent to the severely disrupted zone in the Algoma slip area lies a zone of lesser, although still serious, impairment. In this zone, abnormally high numbers of oligochaetes were found with *Limnodrilus hoffmeisteri* assuming a strongly dominant position in the community. Dominance of *L. hoffmeisteri* has long been recognized as an indication of a disturbed environment (15,16). The success of this species in a polluted situation is due to its ability to tolerate low oxygen levels and high concentrations of most contaminants and to dominate the community in the absence of competition and predator stress. This species, as most other soft bodied invertebrates, is intolerant of elevated levels of heavy metals. Its success in this zone indicates either that the concentrations of iron and zinc in the sediments were below those required to impair the survival of this species or that the organisms present had developed a tolerance to heavy metals.

Zone of Moderate Impairment

Downstream from Algoma discharges and behind the log boom, the benthic community was dominated by tubificids, notably *Limnodrilus hoffmeisteri* and *claparedianus*, and by midges. With the exception of a small population of *Stylodrilus heringianus*, no intolerant organisms were found in this zone indicating that the recovery from severe disruption is only partial here. Disruption of the benthic community in this zone reflects the impaired quality of sediments which contain high levels of ether soluble and phenolic compounds.

Adjacent to the Algoma Steel landfill and disposal area, the benthos was limited to tubificids, leeches and midges all of which were present at densities below 100 individuals/m². Low species diversity, lack of intolerant species and dominance of *Limnodrilus hoffmeisteri* characterized this benthic community. High concentrations of zinc and iron in the sediments together with elevated levels of phenolic and ether soluble compounds likely contributed to the disruption of benthos. The species composition on the U.S. side of the river in this reach was similar to that found in embayment areas upstream from all discharges. The benthic community appeared healthy and was dominated by midges and the isopod *Lirceus*.

Benthic Community Downstream from Algoma Main Trunk Sewer Outfall

Complete recovery of the benthic community was delayed by the introduction of Algoma and Abitibi effluents into the river. The zone of impairment was restricted to a narrow band extending along the Canadian shore for a distance of 2 km. Partial recovery was observed to take place downstream from this zone. The benthic community on the U. S. side of the river downstream from Algoma and Abitibi outfalls did not appear to be affected by these discharges.

Zone of Severe Toxicity

For a distance of approximately 3 km downstream from the discharges, the abundance and diversity of species were greatly depressed. The zone of impairment was restricted to a band approximately 500 m wide hugging the Canadian shore. At a majority of the stations, tubificids, midges, clams and nematodes were present to the exclusion of all other types of macroinvertebrates. The currents in this section are swift and the bottom sediments constantly shifting and eroding. This unstable nature of the substratum together with elevated levels of cyanide, ether soluble compounds and the presence of wood undoubtedly contributed to the disruption of benthos.

Zone of Strong Tubificid Dominance

Three kilometres downstream from the discharges, individuals increased by two orders of magnitude from that recorded upstream and exceeded 10,000 individuals/m². The most dramatic rise occurred in the tubificid family, especially the dominant species *Tubifex tubifex*, *Limnodrilus hoffmeineri* and *Limnodrilus claparedianus* all of which are characteristic of heavily polluted areas. This zone of high oligochaete densities extended for a distance of 0.7 km and paralleled the zone of extensive wood accumulation.

Zone of Moderate Impairment

Five kilometres downstream from the discharges a partial recovery of the benthic community was observed. The species diversity in this zone was high although more sensitive forms of invertebrates such as mayflies and caddisflies were still absent.

Benthos on American Side of the River

A healthy benthic community was found to inhabit the U. S. side of the river. Down from St. Marys Falls and locks, the macroinvertebrate community was highly diverse and included

Zone of Complete Recovery

Complete recovery of the benthic community in the St. Marys River was evident at the outlet of Lake George where midges, snails and clams exhibited weak dominance and mayflies and caddisflies were present.

Benthos on American Side of the River

The zone of strong tubificid dominance extended to the American side of the river near the STP outfall. Impairment of zoobenthos on the American side was localized since the major effect was confined to the Canadian shore.

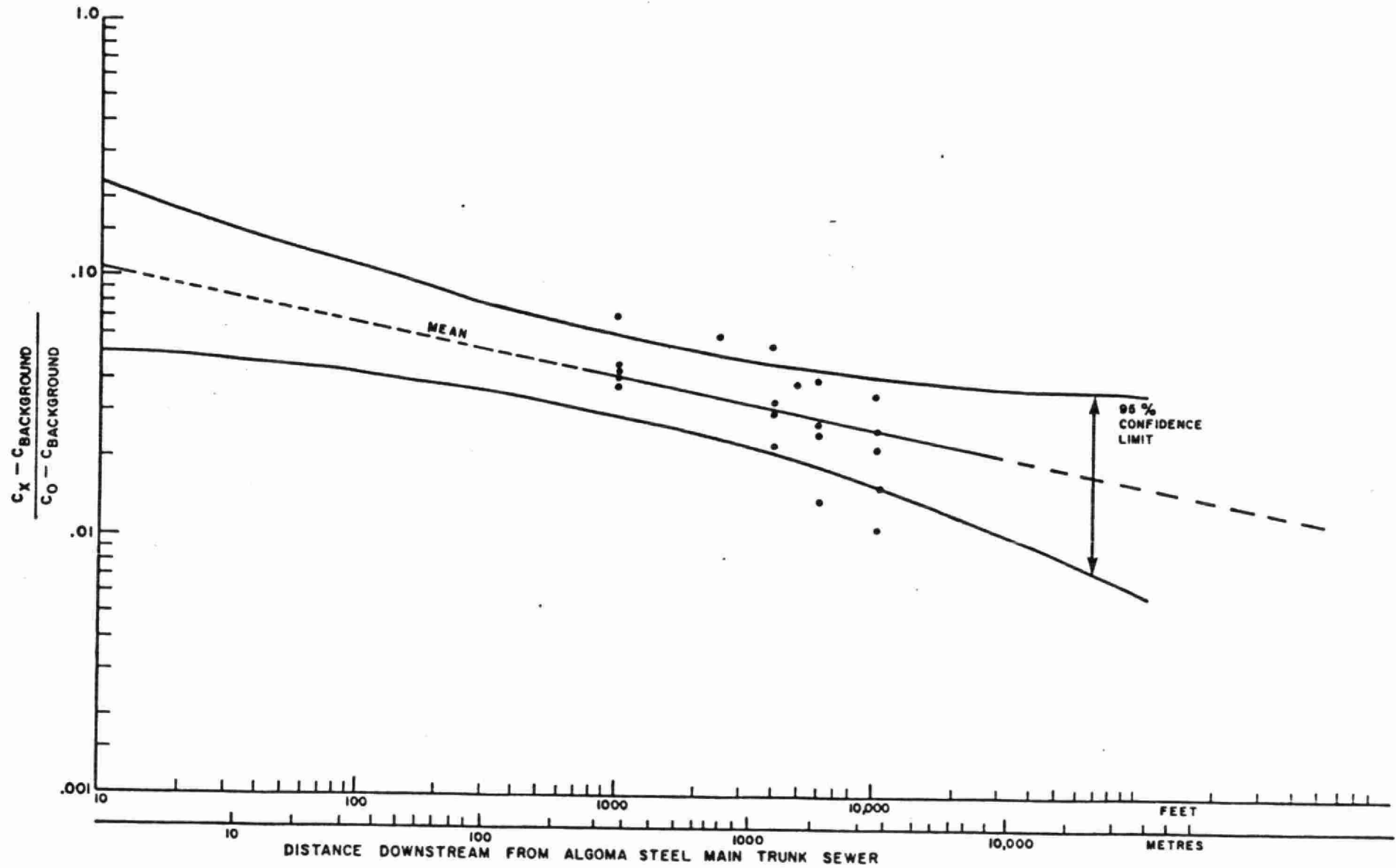


FIGURE 21: RELATIVE CONCENTRATION OF PHENOLS ALONG CANADIAN SHORE

TRANSBOUNDARY MOVEMENT AND MIXING ZONES OF INDUSTRIAL AND MUNICIPAL DISCHARGES

The main trunk sewer of the terminal basin for Algoma Steel Corporation Limited is a submerged diffuser outfall extending 45.5 m from the Canadian shore. The diffuser is equipped with 5 ports which discharge vertically. The ports are rectangular and spaced every 7.5 m. Waterhead above the outfall ranges from 4.2 m to 6 m measured from the minimum and maximum monthly mean water level, respectively. Since the ports are closely spaced, it is likely that considerable interference between jet plumes of adjacent ports occurs. This interference would reduce the initial mixing by about 30% (17).

Figure 21 shows the total dilution factors for phenols occurring along the Canadian shore for the years 1973 and 1974. It was assumed that any degradation of phenol due to biological activity is small. It can be shown that initial dilution of not more than 10:1 takes place just downstream from the outfall. It is also evident that a dilution of 40:1 occurs at a distance of 17 km, reflecting a slow mixing process along the Canadian shore. This is mainly due to irregularity of the shoreline coupled with the lateral force exerted by the discharge from the Edison Sault hydroelectric power canal.

These constraints have elucidated the distribution of phenols in the river as shown in Figure 22. Iso-concentration contours for phenols are deflected towards the Canadian shore and follow the channel to the north of Sugar Island via the Lake George Channel. The curving flow at the beginning of the channel creates a zone of high velocity towards the U.S. shore; secondary currents may be induced due to the variation in the centrifugal force (18). These secondary currents may help increase the transverse mixing process (19). Thus, contaminants would be confined to the Canadian shore at the beginning of the Lake George Channel and then disperse laterally and impinge on the U. S. shore farther downstream, reflecting the occurrence of the transboundary movement in the channel. In summary, discharges of phenolic substances by Algoma Steel are mainly confined to the Canadian shore and constitute transboundary pollution only in the Lake George Channel.

An attempt was made to define the areal extent of mixing zones for industrial and municipal discharges.

It may be assumed that the maximum extent of the mixing zone is equivalent to the initial increment of the dispersion distance (L) defined by Syare & Chang (20). Beyond this distance, a uniform distribution of contaminants is attained. The initial increment is given by:

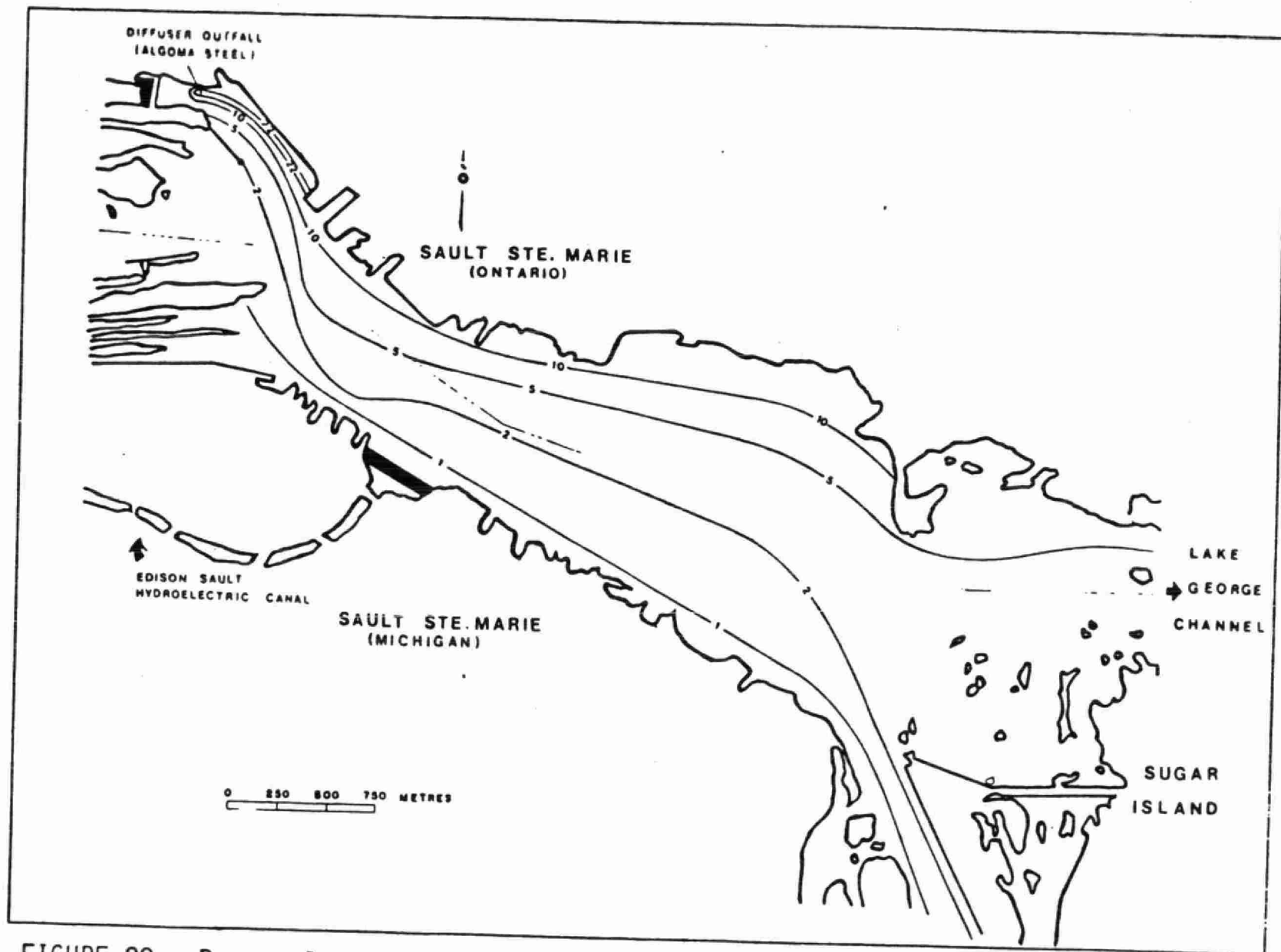


FIGURE 22: PHENOL ISO-CONCENTRATION CONTOURS - 1974

$$L = 1.8 \frac{h}{k} \frac{U}{U_*} \quad (1)$$

where: h is the local water depth
 k is the Von-karmen constant = 0.4
 U is the local stream velocity
 U_* is the local shear velocity.

Shear velocity can be obtained using Manning's formula and approximating the hydraulic radius to the depth of the river:

$$U_* = U \frac{n \sqrt{g}}{(1.486) h^{1/6}} \quad (2)$$

where: $g = 32 \text{ ft/sec}^2$
 substituting value of n (Manning's roughness coefficient) = .0352 (personal communication U.S. Corps of Engineers, Detroit) for the river, equation (2) will be reduced to:

$$U_* = 0.134 \frac{U}{h^{1/6}}$$

Based on actual measurements for the stream velocities during 1974 at each station along transects at 1000 and 4200 ft. from the Algoma Steel main trunk sewer, the following outlines the initial increment of dispersion distance from the outfall.

Distance from Source	Distance from the Canadian Shore	U (ft/s)	h (ft)	U_* (ft/s)	L (ft)
1000	100	1.47	13.2	.128	700
	200	2.11	19.8	.172	1100
	300	2.17	23.1	.172	1300
4200	200	1.40	24.8	.110	1400
	500	.74	29.8	.056	1750
	1000	1.01	33	.076	1970

It can be shown that the nearshore waters have a smaller dispersion distance than those offshore.

Consequently, as a conservative estimate, the mixing zone of Algoma Steel discharges should be restricted to a distance of 1300 ft. from the source to protect and enhance recreational activities, aesthetic enjoyment and public water supply. Furthermore, the proposed extent of the mixing zone can be justified by the following aspects:

- a) The shallow waters around Sugar Island and those surrounding the islands situated downstream are important for the production of zooplankton, invertebrate species and cold water fishery. Moreover, the gravel substratum near the Canadian shore coupled with low current velocities is suitable for spawning of fishes frequenting the river.
- b) As indicated earlier, the combined effect of toxicants as phenol, cyanide and ammonia in water may extend a distance of 1.3 to 3 km from the Algoma Steel outfall. In addition, the abundance and diversity of benthic fauna species were greatly depressed for a distance of 3 km from the outfall.
- c) Since the major transport of pollutants from Algoma Steel takes place along the north side of Sugar Island through the Lake George Channel, interference of contaminants from the STP with those of Algoma delayed the recovery of the river and affected the U.S. shore of the channel due to transboundary movement.

By employing a similar analysis for the STP effluent in Lake George Channel, it was found that a mixing zone of the effluent can be restricted to a linear distance of 600 ft. from the source. It is felt that the above proposed areal extent of the STP effluent mixing zone should alleviate the impact on the U.S. shore of the Lake George Channel.

It should be pointed out, however, that the proposed mixing zones for the industrial and municipal discharges should not be considered as a substitute for proper treatment.

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St. Mary's river

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